Major R. Miles, M.Eng.
President, 1942–43.

PROCEEDINGS
OF THE
INSTITUTE OF BRITISH FOUNDRYMEN

VOLUME XXXV. 1941-1942

Containing the Papers presented to the Thirty-Ninth Annual General Meeting of the Institute and a selection of the Papers presented to the Branch Meetings held during the Session 1941-1942.

Edited by J. BOLTON, Acting Secretary

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The Institute of British Foundrymen

Founded 1904. *Incorporated by Royal Charter,* 1921.

Officers, 1942-43

PRESIDENT.

Major R. Miles, M.Eng., Teesdale Ironworks, Thornaby-on-Tees.

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D. H. Wood, " Cotswold," Barnt Green, Birmingham.

JUNIOR VICE-PRESIDENT :

D. Sharpe, Saracen Foundry, Glasgow, N.

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(Surviving Past-Presidents are ex-officio members of the Council.)

R. Buchanan. (Deceased, 1924.) 1904–1905.
H. Pilkington. (Deceased.) 1906–1907.
F. J. Cook, M.I.Mech.E., 31, Poplar Avenue, Edgbaston, Birmingham, 17. 1908–1909.
P. Longmuir, M.B.E., D.Met., (Deceased, 1942.)
C. Jones. (Deceased, 1923.) 1912.
S. A. Gimson, J.P. (Deceased, 1938.) 1913–1914.
W. Mayer. (Deceased, 1923.) 1915.
J. Ellis. (Deceased, 1930.) 1916–1917.
T. H. Firth. (Deceased, 1925.) 1918.
John Little, M.I.Mech.E. (Deceased, 1932.) 1919.
Matthew Riddell. 1920.
Oliver Stubbs. (Deceased, 1932.) 1921.
H. L. Reason. 1922.
Oliver Stubbs. 1923.
R. O. Patterson, Pioneer Works, Blaydon-on-Tyne. 1924.
J. Cameron, J.P., Cameron & Roberton, Ltd., Kirkintilloch, Scotland. 1925.
V. C. Faulkner, F.R.S.A., 3, Amersham Road, High Wycombe, Bucks. 1926.
J. T. Goodwin, M.B.E., M.I.Mech.E., Grove Hill, Newbold Moor, Chesterfield, 1927.
S. H. Russell, Bath Lane, Leicester. 1928.
Wesley Lambert, C.B.E., 6, King's Avenue, Parkstone, Dorset. 1929.
F. P. Wilson, J.P., " Parkhurst," Middlesbrough. 1930.
A. Harley, " Ashlea," 11, East Ave., Stoke Park, Coventry. 1931.
Victor Stobie, M.I.E.E., (Deceased, 1940). 1932.
C. E. Williams, J.P., " Coniston," Cefn-Coed Road, Roath Park, Cardiff. 1933.
Roy Stubbs, 36, Broadway, Cheadle, Cheshire. 1934.
J. E. Hurst, J.P., D.Met., " Ashleigh," Trent Valley Road, Lichfield, Staffs. 1935.
H. Winterton, Moorlands, Milngavie, Dumbartonshire. 1936.
C. W. Bigg, " Selworthy," Burley Lane, Quarndon, Near Derby. 1937.
J. Hepworth, J.P., M.P., Woodhill Grange, Woodhall Hills, nr. Stanningley, Yorks. 1938.
W. B. Lake, J.P., Albion Works, Braintree, Essex. 1939–1940.
Major R. Miles, M.Eng., Teesdale Ironworks, Thornaby-on-Tees. 1941.

HON. TREASURER :

S. H. Russell, Bath Lane, Leicester.

SECRETARY :

T. Makemson, Assoc.M.C.T.

ACTING SECRETARY AND GENERAL OFFICE :

J. Bolton,
St. John Street Chambers, Deansgate, Manchester, 3.
Registered Office : 49, *Wellington Street, Strand, London, W.C.*2.

AUDITORS

Messrs. J. & A. W. Sully & Co., Parliament Mansions, Abbey Orchard Street, Victoria Street, London, S.W.1.

COUNCIL.

Delegates Elected at Annual General Meeting

H. Bunting, 11, North Avenue, Darley Abbey, nr. Derby.
V. Delport, 7, Kenton Gardens, Kenton, Harrow, Middlesex.
A. B. Everest, Ph.D., B.Sc., Mond Nickel Co., Ltd., Grosvenor House, Park Lane, London, W.1.
J. W. Gardom, Cromer House, Ripley, Derbyshire.
Barrington Hooper, C.B.E., 3, Amersham Road, High Wycombe, Bucks.
E. Longden, A.M.I.Mech.E., 11, Welton Avenue, Didsbury Park, Manchester, 20.
F. K. Neath, B.Sc., Hollywell House, Armley, Leeds, 12.
A. Phillips, 1, Melfort Drive, Edge Lane, Stretford, Manchester.
P. A. Russell, B.Sc., Bath Lane, Leicester.
D. Sharpe, W. MacFarlane & Co., Ltd., Saracen Foundry, Glasgow, N.

Branch Delegates.

(*Branch represented shown in brackets.*)

R. Ballantine, Duncruin, North Street, Motherwell, Lanark (Scottish).
N. C. Blythe, 24, Bagnell Road, Kings Heath, Birmingham, 14 (Birmingham).
L. W. Bolton, A.M.I.Mech.E., 21, St. Paul's Square, Birmingham, 3 (Birmingham).
C. C. Booth, J.P., Mildmay Ironworks, Burnham-on-Crouch, Essex. (London).
W. Y. Buchanan, "Dunconnell," Thomson Avenue, Johnstone, Renfrewshire (Scottish).
W. N. Cook, B.Sc., 10, Stanley Road, Heaton Moor, Stockport (Lancs.)
J. W. Donaldson, D.Sc., Scott's Shipbuilding & Engineering Co., Ltd., Greenock, Renfrewshire (Scottish).
A. Hares, 20, Greenbank Road, Hanham, Bristol (Wales & Mon.).
W. Holland, 24, Trescoe Avenue, Kings Road, Edge Lane, Stretford, Manchester (Lancs.).
C. H. Kain, Lake & Elliot, Ltd., Albion Works, Braintree, Essex (London).
B. B. Kent, Cerne Easter, Westerham, Kent (London).
A. L. Key, 8, Rivington Road, Pendleton, Salford, 6 (Lancs.).
H. W. Lockwood, Stewarts and Lloyds, Ltd., Broad Street Chambers, Birmingham 1 (London).
J. E. Mercer, "Garden Well," Thornton, Stainton-in-Cleveland, near Middlesbrough (Middlesbrough).
A. E. Peace, "Caerhayes," Evans Avenue, Allestree, Derby (East Midlands).
W. H. Salmon, Assoc. Met., 38, Glebe Road, Crooksmoor, Sheffield, 10 (Sheffield).
J. J. Sheehan, A.I.C., A.R.C.Sc.I., 187, Tessal Lane, Northfield, Birmingham (Birmingham).
J. N. Simm, 61, Marine Drive, Monkseaton, Northumberland (Newcastle).
W. H. Smith, "Ryton," Grange Avenue, Normanton, Derby (East Midlands).
F. E. Steele, 130, Birley Moor Road, Frecheville, Sheffield (Sheffield).
W. G. Thornton, "Riverslea," Cottinglea Bridge, Bingley, Yorks (W.R. of Yorks).
W. Williams, Alexandra Brass Foundry, East Dock, Cardiff (Wales and Monmouth).
A. S. Worcester, 162, Victoria Road, Lockwood, Huddersfield (W.R. of Yorks).
J. G. Pearce, M.Sc., M.I.E.E., M.I.Mech.E., F.Inst.P., Alvechurch, Birmingham.

Branch Presidents and Hon. Branch Secretaries.

(*Ex-officio Members of Council.*)

BIRMINGHAM.

T. H. Gameson, 47, Somerset Road, Handsworth Wood, Birmingham, 20.
A. A. Timmins, F.I.C., 54, Carter Lane, Quinton, Birmingham, 32.

EAST MIDLANDS.

G. L. Harbach, Windsor Lodge, Coddington Road, Newark, Notts.
S. A. Horton, "Three," Moston Avenue, Littleover, Derby.

LANCASHIRE.

E. J. L. Howard, "Apsleydene," Altrincham Road, Wilmslow, Cheshire.
H. Buckley, "Ellesmere," Norfolk Avenue, Burnley, Lancs.

LONDON.

R. B. Templeton, White Cottage, Denham, Bucks.
V. C. Faulkner, 3, Amersham Road, High Wycombe, Bucks.

MIDDLESBROUGH AND DISTRICT.

F. Swift, 6, Pierrepoint Drive, Darlington.
J. K. Smithson, North Eastern Iron Refining Co., Ltd., Stillington, Stockton-on-Tees.

NEWCASTLE-UPON-TYNE.

E. B. Ellis, 8, Richmond Terrace, Gateshead-on-Tyne.
C. Lashly, M.C., Close Works, Gateshead-on-Tyne.

SCOTTISH.

R. D. Kirby, "Thisby" Manse Road, Newmains, Lanarks.
J. Bell, 60, St. Enoch Square, Glasgow, C.1.

SHEFFIELD.

T. R. Walker, M.A., 11, Broomgrove Crescent, Sheffield, 10.
W. Webb, B.Sc., 20, Brookfield Avenue, Swinton, Mexborough, Yorks.

SOUTH AFRICAN.

D. Lion Cachet, Box 198, Germiston, South Africa.
F. C. Williams, Mutual Buildings, Corner Harrison and Commissioner Streets, Johannesburg.

WALES AND MONMOUTH.

J. F. Gist, The Paddocks, Frenchay, Bristol.
A. S. Wall, 14, Palace Avenue, Llandaff, Cardiff.

WEST RIDING OF YORKSHIRE.

F. Oldershaw, 39B, Denby Dale Road, Wakefield, Yorks.
S. W. Wise, 110, Pullan Avenue, Eccleshill, Bradford, Yorks.

Section Presidents and Hon. Section Secretaries.

These sections are part of the Branches with which they are associated. The following officers are invited to attend Council Meetings.

EAST MIDLANDS—LINCOLN SECTION.

H. J. Read, 40, Windsor Avenue, Newark, Notts.
E. R. Walter, Ph.D., Technical College, Lincoln.

LANCASHIRE—BURNLEY SECTION.

I. Clayton, 3, Industrial Street, Todmorden, Lancs.
H. Buckley, "Ellesmere," Norfolk Avenue, Burnley, Lancs.

LONDON—EAST ANGLIAN SECTION.

C. J. Lake, Albion Ironworks, Braintree, Essex.
J. L. Francis, A.M.I.Mech.E., Ranelagh Works, Ipswich, Suffolk.

SCOTTISH—FALKIRK SECTION.

G. C. Wilson, 153, Main Street, Camlon, Falkirk, Stirlingshire.
T. R. Goodwin, 126, Main Street, Bonnybridge, Stirlingshire.

WALES AND MONMOUTH—BRISTOL SECTION.

F. Jackson, "Dunbar," The Hollow, Bath.
A. Hares, 20, Greenbank Road, Hanham, Bristol.

Honorary Corresponding Members of Council.

AUSTRALIA: W. T. Main, T. Main & Sons (Pty.), Ltd., Lambert Street, Richmond, E.1, Victoria, N.S.W.
SOUTH AFRICA: A. H. Moore Standard Brass Foundry, Benoni, Transvaal.

AWARDS 1941-42.

THE "OLIVER STUBBS" GOLD MEDAL

1942 Award to Mr. S. H. RUSSELL, Past President and Honorary Treasurer.

"in acknowledgement of the educational work which he has undertaken for many years as Chairman of the City & Guilds of London Institute Advisory Committee on Examinations in Foundry Practice and Science; the contributions which he has made to the discussions on papers at Branch meetings; his work as Honorary Treasurer of the Institute, and his Chairmanship of the Organisation Committee responsible for drafting the proposed new rules."

The Oliver Stubbs Medal has been awarded as follows :—

1922.—F. J. Cook, M.I.Mech.E.
1923.—W. H. Sherburn.
1924.—John Shaw.
1925.—A. Campion, F.I.C.
1926.—A. R. Bartlett.
1927.—Professor Emeritus Thomas Turner, M.Sc.
1928.—J. W. Donaldson, D.Sc.
1929.—Wesley Lambert, C.B.E.
1930.—James Ellis.
1931.—John Cameron, J.P.
1932.—J. E. Hurst, D.Met.
1933.—J. W. Gardom.
1934.—V. C. Faulkner.
1935.—No Award.
1936.—F. Hudson } Two Awards.
E. Longden }
1937.—P. A. Russell, B.Sc.
1938.—S. E. Dawson, F.I.C.
1939.—J. G. Pearce, M.Sc., M.I.E.E., M.I.Mech.E., F.Inst.P.
1940.—A. E. Peace.
1941.—J. J. Sheehan, B.Sc., A.R.C.Sc.I., A.I.C.
1942.—S. H. Russell.

THE MERITORIOUS SERVICES MEDAL

The 1942 Award was made to Mr. S. W. WISE, in recognition of the considerable service he has rendered to the Institute during thirty years of membership. Mr. Wise has been Registrar and a Vice-President of the Newcastle Branch, an examiner for the John Surtees' Memorial Examinations, and for the past sixteen years has been Honorary Secretary of the West Riding of Yorkshire Branch.

The Meritorious Services Medal has been awarded as follows :—

1933.—F. W. Finch.
1934.—J. J. McClelland.
1935.—H. Bunting.
1936.—J. Smith.
1937.—No Award.
1938.—No Award.
1939.—J. E. Cooke.
1940.—J. Bell.
1941.—H. W. Lockwood.
1942.—S. W. Wise.

THE "E. J. FOX" GOLD MEDAL

The 1942 Award was made to Mr. P. H. WILSON, Assistant Managing Director (Technical) of the Stanton Ironworks Co., Ltd., for his work in the development of the centrifugal casting process for the production of cast iron pipe.

The E. J. Fox Gold Medal has been awarded as follows :—

1937.—Professor Emeritus Thomas Turner, M.Sc.
1938.—J. E. Hurst, D.Met.
1939.—Dr. Harry A. Schwartz.
1940.—W. J. Dawson.
1941.—P. Pritchard.
1942.—P. H. Wilson, M.I.Mech.E.

DIPLOMAS OF THE INSTITUTE

were awarded to :—

Mr. A. B. BILL, for his Paper on "Control in a Repetition Foundry," presented to the Lancashire Branch.

Mr. F. G. BUTTERS, for his Paper on "Pattern Equipment for Quantity Production of Small and Medium Castings," presented to the East Midlands Branch.

Mr. E. J. KELLY, for his Paper on "Moulding Problems in the Electric Steel Foundry," presented to the Wales and Monmouth Branch.

Mr. J. G. PEARCE, M.Sc., for his Paper on "British National Specifications for Cast Iron," presented to the Annual Meeting, 1941.

THE "EDWARD WILLIAMS" LECTURE

The following Lectures have now been delivered :—

1935.—"Man and Metal" (delivered at Sheffield)—Sir William J. Larke, K.B.E.
1936.—"Cast Iron and the Engineer" (delivered at Glasgow)—Prof. A. L. Mellanby, LL.D., D.Sc.
1937.—"Factors in the Casting of Metals" (delivered at Derby)—C. H. Desch, D.Sc., Ph.D., F.R.S.
1938.—Not delivered.
1939.—"The Atomic Pattern of Metals" (delivered in London)—Prof. Sir Lawrence Bragg, O.B.E., M.C., D.Sc., M.A., F.R.S.
1940.—Not delivered.
1941.—Not delivered.
1942.—"Foundry Teamwork" (delivered in London)—Dr. H. W. Gillett. (The lecture was delivered on behalf of the author by J. G. Pearce, M.Sc., F.Inst.P.).

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EDITORIAL NOTE

Owing to the considerable number of contributions received by the Institute during the past year, some variations to the normal style of the "Proceedings" have had to be made in order to include a representative selection of Papers within the limits of a volume the size of which has been restricted by limitations in the supply of paper. These economies have enabled the Institute to publish a volume containing as much material as a normal pre-war volume. Even so, it has been impossible to include the following papers which were of a standard which in normal times would have made them eligible for inclusion in the "Proceedings":—

THE USE OF PRECAST PARAFFIN WAX; by H. Holdsworth and P. L. Ward (presented to the South African Branch), see "Foundry Trade Journal," December 11, 1941, page 377.

PLASTER PATTERNS FOR FOUNDRY USE; by H. Plucknett (presented to the Wales and Monmouth Branch), see "Foundry Trade Journal," January 15, 1942, page 35.

METALLURGICAL LITERATURE—ITS CO-ORDINATION AND DIFFUSION; by E. R. Francis, B.Sc. Hons. (Lond.), B.Sc. (Lond.), A.L.A. (presented to the London Branch), see "Foundry Trade Journal," March 19, 1942, page 177, March 26, 1942, page 195, and April 16, 1942, page 245.

RECENT DEVELOPMENTS IN SAND TESTING; by W. Y. Buchanan (presented to the Scottish Branch), see "Foundry Trade Journal," April 30, 1942, page 31, and May 7, 1942, page 51.

The Institute of British Foundrymen

ANNUAL GENERAL MEETING

The thirty-ninth annual general meeting of the Institute of British Foundrymen was held at the Waldorf Hotel, London, on Saturday, June 20, Major R. Miles, M.Eng., the President, in the chair.

Minutes

The minutes of the preceding annual general meeting, held in Manchester on July 12, 1941, were, on the motion of Mr. H. Winterton (Past-President), seconded by Mr. V. Delport, taken as read and were confirmed and signed.

Annual Report Presented

The PRESIDENT presented the annual report of the Council for the year 1941-42, which had been circulated, and called attention to the considerable increase of membership during the past year. The total of more than 2,400 constituted a record. On the motion of the President, seconded by Mr. V. C. Faulkner (Past-President), the report was adopted without discussion.

Balance Sheet

MR. S. H. RUSSELL (Past-President, Hon. Treasurer), presenting the accounts and balance sheet to December 31, 1941, commented on some of the items in the Income and Expenditure Account. Branch expenses in Great Britain had increased slightly, which was a healthy sign. The precaution had been taken of eliminating the item for furniture and fittings, except for £1; the items for air-raid precautions and war damage insurance were new items. The excess of income over expenditure, at £864 12s. 3d., was very satisfactory; he had never anticipated that that position could have been attained at the present rates of subscription. The income from subscriptions constituted a record; some of the Branches had increased their membership very substantially, and as a result the Institute's funds had benefited substantially. In accordance with the decision made a year ago, a certain amount of the reserve funds had been transferred to the Charter Reserve Fund; that had been built up to £400, which would be more than adequate to meet the heavy expenses and charges which it was believed would be incurred when the Institute applied for a new Charter. A sum of £250 was taken from the 1940 surplus, and £150 from the 1941 surplus. Mr. Russell proposed the adoption of the accounts and balance sheet.

MR. W. B. LAKE, J.P. (Past-President), who served as Hon. Treasurer for some years, seconded. He congratulated Mr. Russell on the excellent balance sheet presented, and congratulated the Institute on having so good a treasurer. The members would be glad to learn that the Council had re-elected Mr. Russell to that office, and that he had kindly consented to continue to serve.

The accounts and balance sheet were adopted.

Report of Technical Committee

MR. J. W. GARDOM (Convener of the Technical Committee), moving the adoption of the Committee's Report, which was published with the Council's Annual Report, said he did not think it reflected fully the work which the members of the Committee had done; he expressed his personal thanks to them, and particularly to Mr. John Bolton, the Institute's acting secretary, for his great help throughout the year.

The Melting Furnaces Report, which had been published to members in 1940 was to be made available to non-members. It covered one of the finest pieces of work the Institute had ever done. The Cast Iron Sub-Committee, of which Mr. P. A. Russell was the Convener, had taken on some new work for the Ministry of Supply in connection with the short supply of low-carbon, low-phosphorus material.

The report of the Costing Sub-Committee, of which Mr. V. Delport was Convener, had been in such demand that supplies had run out, and it had been decided to re-publish it; the Sub-Committee would effect some revision. The Steel Sub-Committee, of which Mr. C. H. Kain was Convener, had undertaken some work on silicosis in foundries. In some parts of the country queries had been raised by Factory Inspectors, and the Sub-Committee was trying to emphasise the necessity for taking proper steps to prevent silicosis.

A new Sub-Committee—the Mechanical Development Sub-Committee—had been formed, and would try to educate, not only the younger members, but all the members, to an appreciation of the advantages of some of the mechanical aids that had been introduced into foundries during the past few years.

MR. J. J. SHEEHAN, seconding the adoption of the report, supported Mr. Gardom's remarks and emphasised the importance of the educational side of the Committee's work.

The report was adopted.

Announcements of Awards

The following awards were announced by the President:—

Oliver Stubbs Gold Medal.—The Council recommended unanimously the award of the Oliver Stubbs Gold Medal for 1942 to Mr. S. H. Russell

(Past-President, Hon. Treasurer), in acknowledgment of the educational work he had undertaken for many years as chairman of the City and Guilds of London Institute Advisory Committee in connection with foundry technical education; the contributions which he has made to the discussions on Papers at Branch meetings; his work as honorary treasurer of the Institute, and his chairmanship of the Organisation Committee responsible for drafting the proposed new rules.

The E. J. Fox Gold Medal.—The Council had resolved to make the sixth award of the E. J. Fox Gold Medal to Mr. P. H. Wilson, assistant managing director (technical), Stanton Ironworks Company, Nottingham, for his work in the development of the centrifugal casting process in the production of cast-iron pipes. The recommendation to the Council was made by the assessors, Sir William Larke, K.B.E., and Dr. J. E. Hurst.

Meritorious Services Medal.—The Council recommended unanimously the award of the Meritorious Services Medal for 1942 to Mr. S. W. Wise, hon. secretary of the West Riding of Yorkshire Branch. Mr. Wise had served as Registrar, and later as a Vice-President, of the Newcastle Branch; shortly after his transfer to the West Riding Branch in 1923 he had become hon. secretary, which position he had held since.

Unfortunately, said the President, Mr. Wise was ill, and was unable to attend the meeting. On the suggestion of Mr. D. Howard Wood (Vice-President), a telegram was sent from the meeting to Mr. Wise, advising him of the award and conveying good wishes for his recovery.

Awards of Diplomas

The SECRETARY (Mr. T. Makemson) announced that the Council had awarded Diplomas for the year 1942 as follow:—

To Mr. A. B. Bill, for his Paper on "Control in a Repetition Foundry," read before the Lancashire Branch.

To Mr. F. G. Butters, for his Paper on "Pattern Equipment for Quantity Production of Small and Medium Castings," read before the East Midlands Branch.

To Mr. E. J. Kelly, for his Paper on "Moulding Problems in the Electric Steel Foundry," read before the Wales and Monmouth Branch.

To Mr. J. G. Pearce, for his Paper on "British National Specifications for Cast Iron," presented to the annual general meeting, 1941.

ELECTION OF OFFICERS

President

DR. J. E. HURST (Past-President), proposing the re-election of Major R. Miles, M.Eng., as President for the ensuing year, offered him the congratulations of the Institute on the success of his presidency during the year 1941-42. The office was arduous, and Major Miles was a busy man; he had accepted the invitation again with his eyes open; there was no doubt that he would carry on as he had done in 1941-42, and possibly would enjoy a still better year in 1942-43.

MR. W. B. LAKE, J.P. (Past-President) seconded with sincere pleasure.

Major Miles was unanimously re-elected, amid applause.

The PRESIDENT, in thanking the members for their renewed confidence, said that, however onerous the duties might be, they were much lightened by the goodwill and sympathetic spirit shown by the Council, the senior Branch officials and the general body of the members; and especially by the keenness and ability of Mr. T. Makemson, Mr. John Bolton and their permanent staff.

Senior Vice-President

The PRESIDENT, proposing the re-election of MR. D. HOWARD WOOD as Senior Vice-President for a second year, said he did so with considerable pleasure. It had caused the Past-Presidents and others concerned considerable difficulty and much cogitation in arriving at a decision upon the nomination of the senior officers and, as had been announced officially, the Council had endorsed the principle that the first post-war conference should be held in one of the large centres of population and of the foundry industry. Birmingham was the next large centre on the rota, and it was hoped that Mr. Wood would preside on that occasion; and may it be soon! In order, however, that there should be no suspicion of stagnation, to give a lead to the Branches, and to distribute the honour despite the war, the Council had decided to ask widely-spread Branches to nominate the Junior Vice-President. Scotland was the first choice, and the name of Mr. Daniel Sharpe would be submitted for election to that office in due course. The arrangements were made only from year to year, of course, but it was hoped that he would be President next year, Mr. Wood meanwhile remaining in office as Senior Vice-President.

It might be thought that that arrangement might entail asking too much of Mr. Wood's good nature; but he had repeatedly placed himself unreservedly in the hands of the Council; the Institute was fortunate in having such a good-hearted, generous and able Senior Vice-President, who rarely missed a meeting, and who worked so unremittingly for the good of the Institute. Therefore, the President proposed with the greatest pleasure the re-election of Mr. Wood as Senior Vice-President for the year 1942-43.

After MR. F. J. COOK (Past-President) had seconded, the proposal was carried with acclamation.

MR. D. HOWARD WOOD then expressed his appreciation of the kindly references made to his work and of his re-election, and assured the members that anything he could do for the Institute, in any capacity, he would do with the greatest pleasure.

Junior Vice-President

MR. H. WINTERTON (Past-President) proposed the election of MR. DANIEL SHARPE as Junior Vice-President for 1942-43. It would take quite a lot of time to extol fully, he said, the virtues of Mr. Sharpe, who held a very high position in the affections and esteem of the members of the Scottish Branch. Having had the privilege of working with him for more than 20 years, he could assure the members that they would find Mr. Sharpe to be one of the most thorough men they had ever appointed to office in the Institute.

MR. D. HOWARD WOOD, seconding, said that during the last 15 years the Institute had had from the Scottish Branch two very excellent Presidents in Mr. John Cameron (whose absence from the meeting was very much regretted) and Mr. Harry Winterton. Everyone was confident that the way in which they had discharged their duties when they had served as Vice-Presidents would be emulated by Mr. Dan Sharpe; no further words were necessary to commend his election.

The proposal was carried with acclamation.

MR. SHARPE, who was formally invested with the Junior Vice-President's jewel, said it was a great honour to him to follow in the footsteps of previous Scottish Presidents, and he hoped that his appreciation of that honour would be reflected in the work he would be able to do for the Institute.

Re-election of Auditors

On the motion of MR. V. DELPORT, seconded by MR. C. H. KAIN, the meeting re-elected as auditors Messrs. J. & A. W. Sully & Company (chartered accountants).

Election of Members of Council

The SECRETARY announced that the scrutineers (Mr. J. K. Smithson and Mr. S. A. Horton) of the ballot for the election of five members to the General Council for a period of two years, had certified that the following had been elected:—Mr. H. Bunting, Dr. A. B. Everest, Mr. J. W. Gardom, Mr. F. K. Neath and Mr. Arthur Phillips.

Greetings to the A.F.A.

DR. HURST recalled that it was the usual practice to exchange greetings with the American Foundrymen's Association on the occasions of the annual conferences, and he suggested that a cable be sent from the meeting to the A.F.A.

MR. F. J. COOK seconded, and the cable (which the meeting unanimously agreed should be forwarded) was worded as follows:—

"Kennedy, American Foundrymen's Association,
222, West Adams Street, Chicago, U.S.A.:
"Institute of British Foundrymen, in annual conference, send cordial greetings and join with you in working for speedy and victorious conclusion of our united efforts.
(Sgd.) Miles (President).
Makemson (Secretary)."

President's Address

The PRESIDENT then presented a short address. (See page 12.)

MR. D. HOWARD WOOD proposed a cordial vote of thanks to the President for a most interesting address.

MR. DANIEL SHARPE seconded.

The vote of thanks was accorded with acclamation, and the President briefly returned his appreciation of the vote of thanks.

Presentation of the Oliver Stubbs Gold Medal

The PRESIDENT, formally presenting the Oliver Stubbs Gold Medal for 1942 to Mr. S. H. Russell, said the Council's recommendation of the award was unanimous and in recognition of Mr. Russell's long service to the Institute. He had joined as an associate member in 1906 (two years after the formation of the Institute), and was elected a member in 1920. He had served as President of the East Midlands Branch, and was elected President of the Institute at the Leicester Conference in 1928. In 1937 he was elected honorary treasurer of the Institute and he had also served as chairman of the Organisation Committee which was responsible for the drafting of the proposed new rules.

One of the activities in which Mr. Russell had been keenly interested was that of foundry technical education. When examinations in foundry practice and science and in pattern-making were commenced by the Institute (through the City and Guilds of London Institute), Mr. Russell was elected Vice-Chairman of the Advisory Committee; later he was elected to the chair of that Committee, and had occupied it with distinction ever since. In addition to his normal duties as chairman, he had personally undertaken the general supervision of the examination standards. Mr. Russell had also been a prolific contributor to the discussions of Papers at Branch meetings.

The medal was formally presented to Mr. Russell, and the members expressed their confirmation of the award by their applause.

MR. RUSSELL, responding, said the award was a great honour which, he confessed, had come to him somewhat unexpectedly. On occasions he had found himself in a somewhat embarrasing position at Council meetings when he had heard his name mentioned during the consideration of such awards; but, quite candidly, he had never expected the award of the Oliver Stubbs Medal.

Work of Education Committee

One factor which pleased him particularly, however, was that the award should have been made to him mainly on account of the help he had been able to give the Institute on the educational side of its work. The work of the Education Committee had mainly devolved into speeding what was known as the Advisory Committee to the City and Guilds of London Institute. Many years ago the foundry and patternmaking examinations, with the City and Guilds as the examining body, were not particularly popular; perhaps they were not very well organised from the practical point of view. At any rate, several representatives of the I.B.F. were nominated to interview representatives of the City and Guilds, who were extremely helpful. As a result, the examination papers were revised, and a Moderating Committee was set up, under the chairmanship of Mr. E. R. Briggs; when Mr. Briggs had resigned, he (Mr. Russell) was asked to take the chair. At that time the duties were pleasureable, interesting and instructive, because, in addition to having the help of the members of the Institute on the Advisory Committee, there was also the help of representatives of the teaching profession and of allied bodies. Unfortunately, since the beginning of the war, the City and Guilds had adopted the policy of not calling any of the Advisory Committee meetings, and the responsibility, to his regret, had been thrown entirely upon himself as chairman. Thus, for any Papers which members of the Institute might not like, he as the examiner must be responsible, inasmuch as he had "vetted" them. An effort was being made to get the Advisory Committee functioning again; failing that, the Education Committee would examine the Papers for the last three years and see that the standard was really satisfactory.

Mr. Russell emphasised, in connection with the educational work with the City and Guilds, that an enormous amount of credit was due to Mr. Makemson (the Institute's General Secretary), for he was the original examiner for the City and Guilds, and had done a tremendous amount of spade work in the preparation of the syllabus. Also, he and the Committee had drawn up another syllabus, which had been in a pigeon hole for several years, for a more advanced form of examination for foundry students. Just as the City and Guilds had an intermediate and a final examination for patternmakers, so it was hoped to have an intermediate and a final for foundrymen. That was due very largely to the work of Mr. Makemson, and the scheme was ready to be put into operation if and when required.

Finally, Mr. Russell again voiced his appreciation of the great honour of being among the select body of recipients of the Oliver Stubbs Medal, and he expressed thanks to the President and the members generally for the way in which they had received the announcment of the award.

Presentation of Meritorious Services Medal

The PRESIDENT announced that the Meritorious Services Medal had been awarded to Mr. S. W. Wise, who unfortunately was unable, through illness, to be present. Mr. Wise was elected an associate member in 1912, and was elected a member in 1919. He had served successively as registrar and as junior and senior vice-president of the Newcastle Branch, and was one of the first examiners for the John Surtees Memorial Examinations. He had presented several Papers to various Branches of the Institute, and was the author of a Paper published in the "Proceedings." Transferred to the West Riding Branch in 1923, he had shortly afterwards become its honorary secretary, and had held that office ever since. He had been instrumental in building up the Branch, which had had less than 50 members when he had become hon. secretary. As branch secretary he was also largely responsible for the successful organisation of the 1938 Annual Conference of the Institute, held in Bradford.

The President handed the medal to Mr. F. Oldershaw (President, West Riding of Yorkshire Branch), and asked him to convey again to Mr. Wise the congratulations of the members and their sympathy with him in his illness.

MR. OLDERSHAW expressed profound regret that Mr. Wise could not be present to receive the medal. He had been a very good servant of the Institute for a number of years. The members of the West Riding Branch were very proud that he was their hon. secretary, and of the fact that the award of the Meritorious Services Medal had gone to him and to Yorkshire, for his work on behalf of the Branch and of the Institute generally.

Presentation of the E. J. Fox Gold Medal

MR. E. J. FOX (the donor of the gold medal which bears his name), presented to Mr. P. H. Wilson (assistant managing director (technical), Stanton Ironworks Company, Nottingham), a diploma as a token, for the time being, of the medal. It was an honour, and obviously a very great pleasure, said Mr. Fox, to be able to make the presentation to his colleague and late associate, Mr. P. H. Wilson, to whom it had been awarded by the assessors mainly for his work in the development of the centrifugal casting process for cast-iron pipes. They had worked together, he continued, for nearly a quarter of a century.

Extolling the abilities of Mr. Wilson as a technician on the subject of cast iron, he recalled the well-known definition of an engineer as a man who could do for 19s. 6d. what any jackass could do for a sovereign. Mr. Wilson had been concerned with the cast iron pipe industry, the products of which were sold at figures such as £6, £7 and £8 per ton; and a man who could make a profit out of them at such prices was by no means a jackass.

Formally presenting the diploma to Mr. Wilson, Mr. Fox said he was indeed proud to have been associated for so many years with a man to whom the Institute of British Foundrymen had paid so great a compliment.

History of Centrifugal Casting

MR. WILSON expressed his appreciation of the honour conferred upon him, though it was difficult, he said, to find words with which to reply adequately to the compliments paid to him by his old chief. Inasmuch as the award was made to him by reason of his work in connection with the development of centrifugal casting, he dealt briefly with the history of that development. About the year 1912 he was experimenting in this country in connection with the centrifugal casting of pipes by a process, involving the use of sand moulds, and which had been patented by Molinder—a Swede. Molinder had had great ideas and had hawked his process all over the world. Mr. Wilson recalled that he personally had been very enthusiastic, and his firm had actually installed a small experimental plant and had produced pipes. Unfortunately, however, the firm with which he was then connected had decided not to proceed with the experiments, although he had visualised the commercial prospects. It was a pity that at that stage they did not go ahead.

Later he had joined Mr. Fox at Stanton, and they had heard of the De Lavaud process of centrifugal casting. De Lavaud was a Frenchman who had lived in Brazil, and he, together with a German named Arens, had developed, or had at least experimented with, a process for the centrifugal casting of pipes in metal moulds. They had taken out quite a number of patents. They had taken their ideas to America, but could not obtain sympathy or support from the American pipe makers. Finally, they had installed a demonstration plant in Toronto, Canada, in 1919. The Stanton Company had heard about it, and had sent a representative to Toronto to inspect it and to report. The most important phase in the development of the process, he considered, was at that time, when Mr. Fox had taken it up in spite of the fact that the Americans had turned it down. It was in a very elementary stage then, and the Stanton Company had commenced to develop it into a commercial proposition. They had had to design and re-design the machine, and an experimental plant was installed at Stanton in 1921. He would be almost afraid to give any idea of the amount of money which the Stanton Company had spent to produce the first pipe; but it was worth while. There was a time when Mr. Fox and himself had been very worried as to whether or not they had made a mistake in trying to develop the process; but, in spite of setbacks, they had persevered, for at least at that stage they had overcome the mechanical difficulties.

Then they proceeded with a large-scale plant, which had come into operation commercially in 1922. During the experimental stages they had had visits from Americans, Germans, French and Belgians, who until then had been sitting on the fence, as it were; although the Americans had been very emphatic about turning down the process in the early days, they had taken it up after seeing the results that were being obtained at Stanton. The Germans had followed that example, then the French and the Belgians. Later the process had been applied in Australia and Japan. All the plants abroad were designed on the lines developed at Stanton. Thus, one might say that Mr. Fox had fathered the process, and perhaps he himself might claim to have mothered it. The offspring had been prolific, because the output had developed, up to the beginning of the present war, to between three-quarters and one million tons of pipes per annum. That represented, not only the output of an important product, but a saving of three-quarters of a million tons of metal per annum.

Of course, there were two phases of the development—the mechanical and the metallurgical. The original pipe machine was revolved by means of a Pelton water wheel. Several improvements were introduced from time to time; 12-ft. pipes were produced originally, but finally they had produced pipes 21 ft. long. Dealing with the metallurgical developments, he said that in the early days of the development of the process the fact was advertised that an ordinary cast iron, normally having a tensile strength of 9 or 10 tons per sq. in., would produce centrifugal castings of 20, or even up to 30 tons per sq. in. High tensile strength in cast iron, however, was very often associated with brittleness; so that the high tensile cast iron, if brittle, was not suitable for a pipe. Thus, a great deal of research had had to be carried out, even involving a complete change in cupola practice and making other changes in order to produce a ductile material. Fortunately, they were able to produce that characteristic in the pipe, and at the same time maintain its high tensile strength.

In conclusion, Mr. Wilson thanked the assessors and the Institute for the great honour conferred upon him by the award of the E. J. Fox medal, which he would treasure for two reasons particularly. In the first place it recalled the work with which he had been associated in past years in connection with the development of centrifugal cast iron pipes; secondly, it bore the profile of his chief, Mr. Fox, with whom he had worked for nearly a quarter of a century.

The Edward Williams' Lecture

The morning's proceedings also included the presentation of the Fifth Edward Williams' Lecture: "Foundry Teamwork," by Dr. H. W. Gillett, Chief Technical Adviser, Battelle Memorial Institute, Columbus, Ohio, U.S.A., which was summarised by Mr. J. G. Pearce. (See page 15.)

MR. PEARCE, at the conclusion of the Lecture, said it had been a pleasure to him to present it, for he had had the opportunity of discussing the matters dealt with therein with Dr. Gillett at the beautifully designed and sumptuous laboratories which were his headquarters at Columbus.

Vote of Thanks

MR. V. DELPORT (European Representative of the American Foundrymen's Association, and a Past-President of the London Branch) had the privilege of proposing a vote of thanks to Dr. Gillett for his Lecture, and to Mr. Pearce for having presented it. As one who was in close touch with American friends, he said he was in a position to state, from his correspondence with them, that they had the strongest desire to help and to co-operate with this country in every activity connected with the war. Even before the United States had entered the war he had received many letters of sympathy from America, particularly at the time when London and other large cities in this country were targets for the enemy's bombs. Mr. Pearce and Mr. Makemson, from their correspondence with American friends, could confirm this.

The members of the Institute had had the opportunity of hearing and reading the Edward Williams Lecture prepared by a representative of the A.F.A., and they would all agree that Dr. Gillett had made a happy choice of subject. The Lecture emphasised the desire for teamwork, not only in the industry, but in connection with the war, and no subject could have appealed more to the members of the Institute. It was the sincere hope of all that the teamwork, which was becoming stronger, between our friends across the Atlantic and ourselves would continue after the war, and would assist in the making of an equitable peace. In thanking Mr. Pearce for the presentation of the lecture, he said the close ties and associations existing between the leading research workers in this country and the United States, such as himself and Dr. Gillett, were of the utmost importance.

MR. G. L. BAILEY (British Non-Ferrous Metals Research Association), seconding, said he was glad of the opportunity to join in the expression of thanks to Dr. Gillett and Mr. Pearce, for several reasons in addition to those mentioned by Mr. Delport. Dr. Gillett, he said, had produced recently a series of very important and extremely interesting reports on various matters connected directly with the war effort; the fact that he had found time to prepare the Edward Williams Lecture indicated how willing and anxious he was to co-operate with the Institute. He was extraordinarily able, always presenting his thoughts and information in such a way that the reader must digest them; the Institute was extremely fortunate in the fact that he had prepared the Lecture. In thanking Mr. Pearce, he said that the masterly manner in which he had presented the Lecture on behalf of the author, at very short notice, and had emphasised the salient points, commanded the admiration of all who had heard him.

The vote of thanks was carried with enthusiasm.

Mr. Pearce, in a brief response, joined with Mr. Bailey in the expression of admiration of Dr. Gillett's unconventional approach to metallurgical matters. The manner in which he illuminated his technical remarks with occasional touches of humour was delightful; and he enjoyed freedom to pursue his examination of metallurgical developments without having his mind occupied with purely administrative matters.

Technical Sessions

In the afternoon, two technical sessions were held simultaneously, one devoted to ferrous subjects and the other to consideration and discussion of the "Reports on Low-Tin and Tin-Free Bronzes and Brasses," submitted by members of the Non-Ferrous Sub-Committee of the Technical Committee.

The ferrous Papers presented were the following: "The Production of Uniform Steel for a Light Castings Foundry," by C. H. Kain and L. W. Sanders; "ArmaSteel—Its Manufacture, Control and Applications," by Carl F. Joseph; and "The Substituting of High-Duty Grey Iron for Steel Castings," by J. Blakiston.

THE 39th ANNUAL REPORT

The annual report of the Institute covers the period May 1, 1941, to April 30, 1942.

Finance

The satisfactory subscription revenue during the past year, together with certain adjustments which the war has caused to be made in the Institute's activities, has again enabled a substantial credit balance to be transferred to the Accumulated Fund.

Membership

From Tables I and II it will be seen that there has been a considerable increase in membership. It is with regret that the Council records the death of nineteen members, namely:—

Lord Austin of Longbridge, K.B.E. Elected Honorary Life Member, 1937.

Mr. A. R. Bartlett, Member, London Branch. Elected 1911. Oliver Stubbs Medallist. Past Branch-President. Diploma Holder.

Mr. S. E. Dawson, F.I.C., Member, East Midlands Branch. Elected 1924. Oliver Stubbs Medallist. Past Branch-President.

Mr. J. Deschamps, Member, London Branch. Elected 1927. Member of the Technical Committee, Steel Castings Sub-Committee.

Mr. F. W. Firth, Member, Sheffield Branch. Elected 1914.

Mr. F. J. Hemming, Member, Birmingham Branch. Elected 1929. Past Branch-President.

Mr. R. W. Kenyon, Member, Lancashire Branch. Elected 1904. Past Vice-President of the Institute. Past Branch-President.

Mr. W. A. Oubridge, M.I.Mech. E., Member, Birmingham Branch. Elected 1918.

Mr. H. A. J. Rang, Member, Newcastle Branch. Elected 1912. Past Honorary Secretary of the Newcastle Branch.

Mr. S. B. Rosser, Member, Wales and Monmouth Branch. Elected 1940.

Mr. J. Smith, Member, Newcastle Branch. Elected 1905. Meritorious Services Medallist, 1936. Past Branch-President.

Mr. Joseph Ward, J.P., LL.D., Member, Sheffield Branch. Elected 1908.

Mr. H. Birch, Associate Member, Birmingham Branch. Elected 1916.

Mr. W. G. Cook, Associate Member, Sheffield Branch. Elected 1914.

Mr. W. W. Davies, Associate Member, Wales and Monmouth Branch. Elected 1940.

Mr. E. A. Tait, Associate Member, Middlesbrough Branch. Elected 1930.

Mr. H. Wagstaff, Associate Member, Lancashire Branch. Elected 1939.

Mr. G. Walker, Associate, Birmingham Branch. Elected 1931.

Mr. J. G. Turnbull, Student, Birmingham Branch. Elected 1937.

Table I.—*Changes in Membership*, 1941–1942

	Subscribing firms.	Members.	Associate members.	Associates.	Associates (students).	Totals.
At April 30, 1941	77	972	1,125	113	30	2,317
Additions and transfers from other grades ..	3	60	122	5	17	207
	80	1,032	1,247	118	47	2,524
Losses and transfers to other grades	—	24	67	20	6	117
At April 30, 1942	80	1,008	1,180	98	41	2,407

Honours Conferred upon Members

The following are amongst those who have been honoured during the past year:—

Mr. W. E. Clement (Member) was made a C.B.E. in the New Year's Honours list.

Mr. W. Machin (Member) was a recipient of the M.B.E., in the New Year's Honours list.

Dr. J. E. Hurst (Member) was appointed a Justice of the Peace for the City of Lichfield.

Mr. Summers Hunter (Member) was appointed a magistrate of Wallsend-on-Tyne.

Dr. T. Swinden (Member) received the 1941 award of the Bessemer Gold Medal of the Iron and Steel Institute.

Mr. P. Pritchard (Member) was elected President of the British Cast Iron Research Association.

Mr. W. B. Lake, J.P. (Past President), Dr. T. Swinden, Mr. P. H. Wilson and Mr. FitzHerbert Wright (Members) were elected Vice-Presidents of the British Cast Iron Research Association.

Mr. J. T. Goodwin, M.B.E. (Past President), was elected an Honorary Member of the British Cast Iron Research Association.

Mr. FitzHerbert Wright (Member) was elected Chairman and Mr. J. D. Carmichael (Member) and Major F. D. Ley (Member) Vice-Chairmen of the Council of Ironfoundry Associations.

Mr. E. R. Walter, Ph.D. (Member), Hon. Secretary of the Lincoln Section, who received his Doctorate during the year, was elected Chairman of the East Midlands Branch of the Institution of Mechanical Engineers.

Awards

E. J. Fox Gold Medal.—On the recommendation of the Assessors, Sir W. J. Larke and Dr. J. E. Hurst, the E. J. Fox Gold Medal for 1941 was awarded to Mr. Percy Pritchard, M.I.A.E., F.R.Ae.S., in recognition of the scientific and technical contributions which he has made to the development of the foundry industry, particularly in the light alloys of aluminium and magnesium. Mr. Pritchard is managing director of Birmid Industries, Limited, Birmingham Aluminium Company, Limited, and the Midland Motor Cylinder Company, Limited.

TABLE II.—*Analysis of Membership at April* 30, 1942.

Branch.	Subscribing firms.	Members.	Associate members.	Associates.	Associates (students).	Totals.
Birmingham	9 (8)	164 (160)	155 (160)	15 (16)	4 (6)	347 (350)
East Midlands	5 (5)	83 (80)	140 (110)	3 (5)	1 (2)	232 (202)
Lancashire	13 (13)	122 (119)	199 (196)	20 (22)	2 (2)	356 (352)
London	10 (10)	215 (205)	134 (132)	3 (3)	— (—)	362 (350)
Middlesbrough	1 (1)	34 (31)	48 (45)	6 (8)	15 (5)	104 (90)
Newcastle	6 (6)	28 (30)	18 (26)	30 (41)	7 (7)	89 (110)
Scottish	7 (7)	96 (91)	194 (191)	4 (3)	4 (1)	305 (293)
Sheffield	6 (6)	83 (87)	62 (62)	2 (2)	— (—)	153 (157)
South African	15 (13)	50 (45)	48 (35)	10 (9)	— (—)	123 (102)
Wales & Monmouth	3 (3)	54 (46)	59 (50)	1 (—)	8 (7)	125 (106)
W.R. of Yorks.	4 (4)	61 (58)	104 (98)	4 (4)	— (—)	173 (164)
Unattached	1 (1)	18 (20)	19 (20)	— (—)	— (—)	38 (41)
	80 (77)	1,008 (972)	1,180 (1,125)	98 (113)	41 (30)	2,407 (2,317)

Figures in brackets are totals at April 30, 1941.

Oliver Stubbs Gold Medal.—The Oliver Stubbs Gold Medal for 1941 was awarded to Mr. J. J. Sheehan, B.Sc., A.R.C.Sc.I., A.I.C., in recognition of the valuable Papers which he has presented to the Institute, to International Foundry Congresses, and to overseas foundry technical associations, and in recognition of the outstanding contributions which he has made to foundry sands research as Convener of the Sands Sub-Committee of the Technical Committee of the Institute.

Meritorious Services Medal.—This medal for 1941 was awarded to Mr. H. W. Lockwood "in recognition of his outstanding services to the Institute particularly as Honorary Secretary of the London Branch, a member of the Council, and of Standing Committees over a period of several years."

Diplomas.—Diplomas were awarded to the following members during the year: Mr. J. F. Webster (Scottish Branch), Mr. A. E. McRae Smith (London Branch), and Mr. J. M. Stones (South African Branch).

John Surtees' Memorial Competition

In the examinations for 1942, arranged by the Scottish Branch, the following were prizewinners:—

Senior Competition.—Gold medal, no award.

Junior Competition.—Silver Medal and First prize, Thomas M. McKinley. Second prize, Robert McArthur. Third prize, James G. Ogilvie. Fourth prize, William Dickson. Two consolation prizes, E. C. Miller and J. F. Steel.

It should be mentioned that these examinations were the first time when both parts of the examinations were completed by every student and in the opinion of the examiners the Papers were the best ever submitted by students in the Scottish Branch.

Edward Williams Lecture

No Lecture was presented in 1941. Dr. H. W. Gillett, of the Battelle Memorial Institute, U.S.A., will present the Lecture in 1942.

Branch Activities

The East Midlands, Lancashire, London, Scottish, West Riding of Yorkshire, and South African Branches have carried out full syllabuses of meetings. Further meetings have been arranged by the Birmingham, Middlesbrough, Sheffield, and Wales and Monmouth Branches. In addition, the East Anglian, Bristol, Burnley, Lincoln and Falkirk Sections have all had full syllabuses of meetings during the past year. At most meetings satisfactory attendances have been recorded. The Council desires to express its special thanks to Branch Councils and secretaries and to the authors of Papers presented at these meetings. The very heavy calls which are being made upon the time of those engaged in the foundry industry make it particularly difficult to carry on the normal Branch activities, but in spite of these difficulties about 70 meetings have been held throughout the country. The South African Branch continues to make steady progress.

Educational Work

The following are the results of the examinations held under the auspices of the City and Guilds of London Institute and in conjunction with the Institute in April and May, 1941:—

	No. of candidates.	Pass 1st class.	Pass 2nd class.	Percentage of passes.
Patternmaking—Intermediate grade	28	11	6	60.7
Patternmaking—Final ..	16	2	8	62.5
Foundry practice and science ..	40	10	12	55.0

Buchanan Medals and Book Prizes were awarded to:—

PATTERNMAKING—*Final.*

Fred Harland Lindsey, Constantine Technical College, Middlesbrough: Buchanan Book Prize.

FOUNDRY PRACTICE AND SCIENCE.

Buchanan Silver Medal.—Frank Hallas, Huddersfield Technical College.

Buchanan Book Prizes.—Donald Colbridge, external candidate of Penistone, near Sheffield; Gordon Benjamin Evans, external candidate of Rochester, Kent; William Hugh Rendall, Dolcoath Technical School, Camborne, Cornwall.

The Council is pleased to note the formation of foundry classes at Ipswich. The establishment of these classes has been due almost entirely to the endeavours of the East Anglian Section of the London Branch, whose members have co-operated with the local educational authorities. It is also recorded that steps have been taken towards establishing foundry classes in the Shropshire area and at Bristol. In this work the Institute is co-operating to the fullest possible extent.

Publications

Volume XXXIV of the Proceedings was published on February 1, 1942. The restrictions on the use of paper together with the smaller number of lectures available for publication limited the size of the volume. During the year a new departure was made in that three Papers were circulated to members of the Institute. It was realised that due to wartime conditions many members would not be able to attend the Branch meetings and this method of publication was adopted in an endeavour to help such members. These Papers were presented before several Branches and discussed. Arrangements have been made for a number of Papers to be presented to the annual general meeting, 1942.

Kindred Associations

Cordial relations continue to exist between the Institute and kindred societies. Relations with overseas associations have, however, been suspended with the happy exception of the American Foundrymen's Association, to which an exchange Paper has been sent on behalf of the Institute by Mr. C. H. Kain and Mr. L. W. Sanders. The 1941 A.F.A. exchange Paper was by Mr. N. J. Dunbeck on "American Synthetic Sand Practice."

The Institute has been pleased to note the formation during the year of the Council of Ironfoundry Associations, of which the Institute has been elected an affiliated member. It is represented on the Executive and Finance Committee by the President, and on the Technical Advisory Committee of the Council by the Convener of the Technical Committee and the Conveners of the Cast Iron and the Malleable Cast Iron Sub-Committees.

Council

Four meetings of the Council and twelve meetings of the Executive and other Standing Committees have been held in Manchester, Leeds and Derby. Of the ten members of the Council who are elected by ballot for a period of two years, five retire each year, those who retire at the annual general meeting to be held in London on June 20, 1942, are: Mr. H. Bunting, Dr. A. B. Everest, Mr. J. W. Gardom, and Mr. F. K. Neath. Mr. H. J. Roe, who was elected a member of the Council in 1941 for one year in place of Mr. R. A. Miles, deceased, will also retire at the annual general meeting, 1942. These gentlemen offer themselves for re-election and are eligible for re-election for a further period of two years.

Officers

The Council unanimously recommends that Major R. Miles, M.Eng., be re-elected President and that Mr. D. H. Wood be re-elected Senior Vice-President. The recommendations will be placed before the annual general meeting on June 20, 1942. A nomination for the office of Junior Vice-President for 1942-43 will be placed before the annual general meeting on June 20, 1942.

The Council wishes to express its thanks to Mr. S. H. Russell, Past-President and Hon. Treasurer, for the careful way in which he has conducted the Institute's finances. The Council is also grateful to Mr. J. W. Gardom, Convener of the Technical Committee, under whose direction the Committee has continued to contribute to the war effort. Details of some of the work done by the Committee cannot be published at the present time, the Council nevertheless wishes to thank Mr. Gardom and the Committee for the excellent work which has been done during the past year.

Annual General Meeting, 1941

The annual general meeting was held at the Midland Hotel, Manchester, on Saturday, July 12, 1941, and was preceded by a luncheon and followed by two technical sessions. It was thought inappropriate to arrange a full conference during the war, the programme was therefore restricted to one day. The Council, bearing in mind the same considerations, has arranged a similar programme for the annual general meeting which is to be held at the Waldorf Hotel, London, on June 20, 1942. The annual general meeting will be followed by the presentation of the Edward Williams Lecture, a luncheon, and a number of technical Papers.

Staff

The Secretary of the Institute, Mr. T. Makemson, whose services have temporarily been loaned to the Iron and Steel Control of the Ministry of Supply, was appointed Joint Director for Iron Castings in October, 1941. The Assistant Secretary, Mr. J. Bolton, has been appointed Acting Secretary of the Institute.

RICHARD MILES, President.
JOHN BOLTON, Acting Secretary.

TENTH ANNUAL REPORT OF THE TECHNICAL COMMITTEE

During the past year the work of the Technical Committee has been continued in an endeavour to assist to the maximum possible extent in the country's war effort. The advisory work which was commenced during the preceding year at the request of the Director for Iron Castings, Ministry of Supply, has been continued and completed during the current year; all the foundries for which the Committee was responsible have now been brought into production. This work necessitated the employment of a full-time technical staff under the Convener's direction; the Sub-Committees, notably the Steel Castings Sub-Committee, of the Technical Committee have also assisted the Convener in the execution of this work. Its confidential nature does not permit publication to be made at the present time, but the Committee has made arrangements for filing the important data collected with a view to full publication later.

The Institute, through the Technical Committee, continues to be represented on the Technical Advisory Panel to the Directors for Iron Castings, Mr. J. W. Gardom, Convener; Mr. P. A. Russell, B.Sc., Convener of the Cast Iron Sub-Committee; and Mr. E. Longden, A.M.I.Mech.E., act as the Institute's representatives.

The Malleable Cast Iron Sub-Committee has also been called upon by the Ministry of Supply to act in an advisory capacity on certain problems connected with the production of malleable cast iron. This Sub-Committee has also been largely responsible, through the British Standards Institution, for drawing up the recently issued wartime revision of B.S.S. 309 and 310 for Blackheart and Whiteheart Malleable Cast Iron.

Mr. A. E. Peace, Convener of the Malleable Cast Iron Sub-Committee, and Mr. P. A. Russell, B.Sc., Convener of the Cast Iron Sub-Committee, and Mr. J. W. Gardom, Convener, represent the Institute on the Technical Advisory Committee of the Council of Ironfoundry Associations which was established during the year and of which the Institute is an Affiliated Member.

The Technical Committee has also been invited by the Mines Department to appoint representatives to a Committee set up by that Department to deal with fuel efficiency and conservation. In accepting the invitation the Technical Committee appointed Mr. T. R. Walker, M.A., and Mr. V. C. Faulkner as representatives.

At the request of the Admiralty, the Non-Ferrous Sub-Committee met to discuss and advise on the conservation of tin in non-ferrous foundries and the introduction of alternative alloys to effect economy. This work has now been completed and publications are being made by the Institute to assist both founders and users in dealing with the proposed modifications. This work necessitated the publication of new British Standards Specifications; the Non-Ferrous Sub-Committee has fully participated in the preparation of these Specifications.

The Technical Committee has, for many years, had a wide representation upon Technical Committees of the British Standards Institution engaged in the preparation of Specifications concerned with cast metals and alloys and with foundry matters generally. In line with the ever-widening scope of the British Standards Institution, the Technical Committee, on behalf of the Institute, has, during the past year, appointed several additional representatives to the British Standards Institution Committees with the result that the Institute is now represented upon two Industry Committees, twelve Technical Committees, and seven Panels of the British Standards Institution.

A number of technical inquiries have been received from members during the year and have been satisfactorily dealt with. Members are invited to submit technical problems to the Committee.

J. W. GARDOM, Convener.

BALANCE SHEET 31st December, 1941

LIABILITIES.

				£	s.	d.	£	s.	d.
SUNDRY CREDITORS				450	0	0			
SUBSCRIPTIONS PAID IN ADVANCE				166	7	6			
SECRETARY'S POLICY FUND				18	8	8			
							634	16	2
THE OLIVER STUBBS MEDAL FUND :—									
Balance from last Account				214	14	5			
Interest to date				10	5	4			
				224	19	9			
Less : Cost of Token				1	9	7			
							223	10	2
THE BUCHANAN MEDAL FUND :—									
Balance from last Account				119	2	4			
Interest to date				4	10	0			
				123	12	4			
Less : Cost of Medals and Prizes				5	1	6			
							118	10	10
THE E. J. FOX MEDAL FUND :—									
Balance from last Account				496	5	2			
Interest to date				16	4	0			
				512	9	2			
Less : Cost of Token				2	3	3			
							510	5	11
TECHNICAL DEVELOPMENT FUND :—									
Balance from last Account				443	10	0			
Interest to date				11	14	4			
							455	4	4
SPECIAL TECHNICAL ACCOUNT FUND :—									
Loans				250	0	0			
Creditors				88	15	5			
							338	15	5
CHARTER RESERVE FUND							400	0	0
ACCUMULATED FUND :—									
Balance 31st December, 1940				3,176	1	9			
Transfer to Charter Reserve Fund				250	0	0			
				2,926	1	9			
Excess Income over Expenditure for the year ended 31st December, 1941	864	12	3						
TRANSFER TO CHARTER RESERVE FUND	150	0	0						
				714	12	3			
							3,640	14	0
							£6,321	16	10

S. H. RUSSELL, *Hon. Treasurer.*
TOM MAKEMSON, *Secretary.*

Parliament Mansions, Victoria Street,
London, S.W.1
1st May, 1942.

ASSETS.

	£	s.	d.	£	s.	d.
CASH IN HANDS OF SECRETARIES :—						
Lancashire Branch	32	15	2			
Birmingham Branch	62	2	7			
Scottish Branch	25	18	10			
Sheffield Branch	47	13	6			
London Branch	19	9	7			
East Midlands Branch	31	8	7			
West Riding of Yorkshire Branch	11	7	9			
Wales and Monmouth Branch	13	1	6			
Middlesbrough Branch	15	6	0			
Newcastle Branch	18	5	0			
South African Branch	52	1	4			
				329	9	10
LLOYDS BANK LTD.				597	15	0
MANCHESTER & SALFORD SAVINGS BANK				509	5	2
CASH IN HAND—SECRETARY'S POLICY FUND	18	8	8			
Do. —HEAD OFFICE PETTY CASH	5	12	6			
				24	1	2
SUNDRY DEBTORS, ETC. :—						
Subscriptions due and subsequently received				65	13	6
SUPERANNUATION INSURANCE :—						
Unexpired premium				18	8	7
THE OLIVER STUBBS MEDAL FUND :—						
£342 5s. 7d. Local Loans 3% Stock at cost	200	0	0			
Balance at Lloyds Bank Ltd.	23	10	2			
				223	10	2
THE BUCHANAN MEDAL FUND :—						
£125, 3½% Conversion Stock at cost	98	6	9			
Balance at Midland Bank, Ltd.	20	4	1			
				118	10	10
THE E. J. FOX MEDAL FUND :—						
£462 19s. 3d., 3½% Conversion Stock at cost	500	0	0			
Balance at Lloyds Bank, Ltd.	10	5	11			
				510	5	11
TECHNICAL DEVELOPMENT FUND :—						
Balance at Manchester & Salford Savings Bank				455	4	4
SPECIAL TECHNICAL ACCOUNT :—						
Cash at Bank	177	12	1			
Cash in hand	11	5	4			
Recoverable expenses	149	18	0			
				338	15	5
INVESTMENTS :—						
£650, 3½% War Loan at cost	630	8	4			
£653 19s. 0d., 3% Local Loans at cost	451	13	8			
£964 5s. 1d., 3% Funding Loan at cost	897	14	11			
£400, Leeds Corporation Mortgage	400	0	0			
£750, 3% Defence Bonds	750	0	0			
				3,129	16	11
FURNITURE, FITTINGS, AND FIXTURES :—						
Balance from last Account	45	2	11			
Less : Amount written off	44	2	11			
				1	0	0
				£6,321	16	10

We have prepared and audited the above Balance Sheet with the books and vouchers of the Institute and certify same to be in accordance therewith.

J. & A. W. SULLY & Co.,
Chartered Accountants, Auditors

INCOME & EXPENDITURE ACCOUNT for the Year Ended 31st December, 1941

EXPENDITURE.

1940 £ s. d.	1940 £ s. d.		£ s. d.	£ s. d.
155 5 1		POSTAGES		176 16 3
866 11 10		PRINTING AND STATIONERY including printing of "Proceedings"		819 12 4
64 1 11		COUNCIL FINANCE AND ANNUAL MEETING EXPENSES		67 12 2
		BRANCH EXPENSES:—		
	104 8 2	Lancashire	103 1 4	
	66 18 10	Birmingham	59 11 3	
	68 8 7	Scottish	76 11 2	
	7 5 9	Sheffield	13 6 6	
	37 3 7	London	62 15 5	
	57 7 7	East Midlands	49 5 7	
	2 19 11	Newcastle	3 10 0	
	37 7 8	West Riding of Yorkshire	48 12 3	
	6 14 3	Wales and Monmouth	17 15 6	
	24 3 2	Middlesbrough	26 15 0	
	135 18 3	South African	50 3 3	
548 15 9				511 7 3
12 12 0		AUDIT FEE AND ACCOUNTANCY CHARGES		12 12 0
114 14 5		INCIDENTAL EXPENSES		84 10 5
		SUBSCRIPTIONS:—		
	10 10 0	British Standards Institution	10 10 0	
	5 5 0	Joint Commission on Materials	5 5 0	
15 15 0				15 15 0
694 16 7		SALARIES: — Secretary and Staff *less* Received		586 4 2
55 5 10		SUPERANNUATION INSURANCE (Secretary)		55 5 10
108 17 5		RENT, RATES, &c., of Office *less* Received		110 1 0
5 0 4		FURNITURE AND FITTINGS— Amount written off		44 2 11
— —		AIR RAID PRECAUTIONS AND FIRE WATCHING		21 19 5
— —		WAR DAMAGE INSURANCE		17 7 0
		JOHN SURTEES MEMORIAL EXAMINATION:—		
9 14 3		Grants to Branches		— —
37 7 11		EXPENSES re PROPOSED CHELTENHAM CONFERENCE		— —
2,688 18 4				2,523 5 9
658 8 8		EXCESS OF INCOME OVER EXPENDITURE CARRIED TO BALANCE SHEET		864 12 3
3,347 7 0				£3,387 18 0

INCOME

	£ s. d.	£ s. d.	1940 £ s. d.	1940 £ s. d.
SUBSCRIPTIONS RECEIVED:—				
Lancashire Branch		472 10 0		511 15 6
Birmingham Branch		529 19 0		408 2 6
Scottish Branch		388 10 0		364 17 6
Sheffield Branch		257 15 6		277 14 6
London Branch		521 17 0		547 11 6
East Midlands Branch		305 0 0		264 11 6
Newcastle Branch		104 3 6		115 13 0
West Riding of Yorkshire Branch		229 19 0		197 2 6
Wales & Monmouth Branch		147 18 6		165 11 0
Middlesbrough Branch		101 5 6		114 7 6
Unattached Members		43 13 0		41 4 0
South African Branch		201 1 6		175 7 0
		3,303 12 6		3,183 18 0
Add:—				
SUBSCRIPTIONS IN ADVANCE 1940	111 5 0		91 12 0	
SUBSCRIPTIONS DUE 1941	65 13 6		75 15 0	
		176 18 6		167 7 0
		3,480 11 0		3,351 5 0
Less:—				
SUBSCRIPTIONS IN ADVANCE 1941	166 7 6		111 5 0	
SUBSCRIPTIONS DUE 1940	75 15 0		33 1 6	
		242 2 6		144 6 6
		3,238 8 6		3,206 18 6
SALE of "PROCEEDINGS," Etc.		27 2 0		39 2 9
INTEREST ON INVESTMENTS AND CASH ON DEPOSITS		97 14 6		97 16 6
JOHN SURTEES MEMORIAL EXAMINATION SURPLUS		24 13 0		2 18 5
PROFIT ON SALE OF BADGES		— —		0 10 10
		£3,387 18 0		£3,347 7 0

PRESIDENTIAL ADDRESS

By MAJOR R. MILES, M.Eng.

This is the second time that I have had the privilege of inflicting a Presidential Address upon you. Owing to the war, it is again not expedient to review and to publish information relating directly to the foundry industry, which is taking so important a part in the war effort. I propose, therefore, to continue, in some measure, the discursive remarks I made last year. These dealt, you may remember, with some of the broader issues arising out of the present situation, in so far as they affected the individual, and especially the individual foundryman. On this occasion, the greater portion of my brief address will be devoted to suggestions for lessening the economic difficulties that will confront us in the immediate post-war period.

The evidence to date indicates that it may be some time yet before we win the war; but it will no doubt take a long time to prepare the reconstruction on the necessary world-wide scale, especially if we are to avoid the difficulties that have always followed the upheavals due to major wars. These preparations will entail planning ahead in some detail, and I am still of the opinion that we shall have to submit to a considerable degree of "control" for some time after hostilities are over.

Reasonable Standard of Living

Fundamentally we must assume a reasonable standard of living. In fact, it is only fair and right that all who are willing to earn a living for themselves and their families should be given an opportunity to do so. Obviously, the only way to earn a living is either to be self-sufficient or to produce goods or services which can be exchanged. Our social organisation to-day is such that the individual is very rarely able to be self-sufficient. Hence the predominating way of earning a living is to produce goods or services which can be exchanged. Under a system of "laissez-faire," employment was determined by its efficiency and usefulness, provided capital was available. This arrangement was sound in that it corresponded with the natural arrangement of the survival of the fittest, and to interfere with it seemed like abrogating the natural order, and putting reason in its place. But man's reason has continually expanded, and I almost think that we have reached a stage where reason should be able to exercise considerable control of man's economic satisfaction. It is a matter of organisation, or, to use the words with which I began this line of thought, of "planning" and "control." Hitherto our technique in this has been poor. But how are we to learn the necessary technique?

As illustrating the difficulty, I could take the case of a hypothetical firm, which employs some 5.000 men. This means that the livelihood of 15,000 to 20,000 people depend directly on the firm being employed, and maybe as many more indirectly. Most works are working over "normal" capacity to-day. A considerable proportion of production is of material that is not required in peacetime. What will be the number of men employed by any firm so placed when peace breaks out again? And what is going to happen to the remainder? Can a scheme be worked out stabilising a given number of peacetime employees and making appropriate arrangements for the others? As the products of a typical large-scale works may range from needle wire to tanks, and multifarious industrial plant, it would obviously be very difficult to make progress by starting at the bottom in such a works; and with the thousands of other works which would require similar consideration.

Incidentally, I may interpolate here that in the case in mind dividends represent 1 per cent. of the turnover. It seems to me that those who spend their time arguing about the administration of some 1 per cent. of the whole have lost their sense of proportion. Politicians are especially prone to such arguments, and this alone would seem to be an indictment of the present party system. The immediate post-war danger will not be the continuation of the perennial conflict between the "haves" and "have-nots," but the avoidance of a situation where very large numbers of people "have not." If hope is included in the "having not," the situation will be serious indeed. We are all agreed that the outstanding consideration is that a reasonable standard of life must be maintained. Our capital—savings, stocks of goods—will be very greatly depleted by the war. Hence the reasonable standard of life must be earned currently.

Organisation in National Groups

The difficulty lies in the organisation of this production, and its distribution to the points of consumption. As I have previously stated, a plan starting from the bottom with the employment of individuals, will soon become too complicated to complete, but it is possible that a fundamental plan could be worked out for major articles of consumption to obtain a rough volume of consumption per annum. It could be done by assuming a certain standard of living, of say a National Group, converting that standard into pounds of this, and yards of that, and so on, that each person requires each year to maintain the assumed standard. I am referring now to the major necessaries, and the calculations would be simplified by taking the minimum quantities of each required to maintain the standard laid down. Having obtained the volume per individual you multiply this volume by your number of individuals in the National Group and obtain the requirements of the Group. You then add all the National Group totals together, and get the grand total of consumption.

I believe it to be a fact that the grand total of production could exceed the grant total of consumption; hence the next step would be to allocate the required production, distributing the effort as nearly as is possible *pro rata* to the consumption, not only to keep everything as fair as possible, but to reduce the transference of other means of exchange to a minimum. Local geographical conditions would have to be borne in mind for various reasons, most of them obvious. A scheme of this sort could be worked amongst such National Groups as would desire to take part, and for the major necessities. Incidentally instead of a " dole," non-transferable coupons or " points " rationing could be instituted for those whose labour could not be immediately absorbed in the main plan.

Post-War Employment

There would remain, I am sure, a large balance of unexpended effort, which could be applied with considerably less control, in the first place, to less necessary consumption goods, in the second place to public works or other capital goods; and in the third place to luxuries. I emphasise, however, in view of the many ill-informed expressions of opinion to the contrary, that the primary absorption of man-power after the war must be in the production of consumption goods, though there is bound to be a certain amount of overlapping both in definition and in time.—You will notice I do not place public works schemes first on the list.—One difficulty that might be raised, is that the National Groups would not agree amongst themselves upon their relative standard. This difficulty would not be so great if the " grab-all " spirit were eliminated, and if the big and strong National Groups would act as older brothers in a family; or rather as older brothers should act in a family. Invidious direct comparisons might be avoided by bulk exchanges of commodities, provided that no matter how poor the Group, they received their minimum standard, if they showed the willingness to work, and could provide some exchangeable commodities.

You can see how easy, one might say inevitable, it would be to slip back, and come to some equilibrium on a system very much like the present, but on a National Group scale, instead of an individual scale. I see no reason to doubt that history will repeat itself. Fourteen hundred years ago we had several kingdoms in England. Eight hundred years ago England and Wales were divided. Four hundred years ago Scotland was a separate country. We may have gone backwards in the case of Ireland, but Ireland is exceptional in many ways. It seems, then, that by a long process of trial and error, many trials and many errors, we shall achieve a Federation of the World, but I have no doubt that we shall still have a carrot just before our noses. If not the same old carrot, perhaps a bigger and better carrot, or maybe the best carrot of all, the ideal carrot, our advanced physicists having proved by that time that the ideal carrot is the real carrot, and will use a development of the quantum theory and wave mechanics to explain why it isn't there when we are not thinking about it!

Some Common Fallacies

Nonsense apart, all I wish to convey is that there is no ready solution " just round the corner." The man who prescribes a panacea for our social ills is a quack, and has not given the subject deep thought. For instance, we hear a lot about the elimination of class distinctions. Class distinctions will not be eliminated. While sets of people have interests similar to each other and different from other sets, so these sets will form classes, irrespective of their worldly wealth. There are people who climb Snowdon, and people who come down the switchback at Blackpool.

" Capitalistic system " is another expression in my opinion erroneously used. By it is invariably meant the " system whereby the private individual can accumulate excessive amounts of capital." All modern production requires capital. The most common form of capital is the bridge which is built to span the gap between the time of production and the time of consumption. The tea in your cup of tea at breakfast was grown by a coolie who required paying a year or two ago. You only paid for your tea last week—if you have paid for it. To bring the tea to this country somebody paid for a ship years ago, and capital is what pays for things years ago so that you can have them to-day. Thus capital is necessary under to-day's conditions. In the robber barons' days their capital was their strong right arm. Germany's capital to-day is its soldiers and their equipment, though they are both being used as revenue and are consequently very heavily taxed!

Return on Capital Indispensable

Whether the State or the private individual controls the use of capital is of secondary, though many people think it of primary, importance. Inevitably modern production methods demand units of increasing size, and frequently only the State can supply the necessary capital even now. The tendency will increase, perhaps even too fast to enable bureaucrats to learn technical efficiency, or technicians to become bureaucrats, as say, in your own cases. There may be some examples, too, where the State, for sentimental reasons, perhaps quite important, and adding to the sum of human happiness, may be content to receive only one grain of corn where two grew before. Even private capitalists have been known to expend large sums for no material return to themselves. But whether capital is employed by the State or the individual, there must be some return on the whole, if material progress is to be made.

Whether the use of private capital in the form of money persists or not, people will always make rewards to their favourites who possess other forms of capital, such as the good looks of the film star, whom democracy rewards very handsomely to-day, or the loud voice of the politician whom they rewarded perhaps in other ways when eggs and perhaps politicians were more plentiful. I do not wish you to infer that I think the whole system so complicated that any large changes for the better are impossible to work out, but I do wish to repeat the warning to suspect sweeping and wholesale claims for any special system.

I believe that the transitional difficulties that I have implied will not impair my main theory of working to an approximate calculation of the minimum major needs, at any rate amongst those national groups who will "play." I would repeat that complete solutions will almost certainly never be within our immediate grasp; but we must all work with goodwill—I emphasise goodwill—and even do a bit of wishful thinking as Mr. Oliver Lyttleton recommended the other day, to make the world, and especially our own immediate world, happier and better as a result of our efforts.

Fifth Edward Williams' Lecture

Paper No. 749

Foundry Teamwork

By Dr. H. W. GILLETT (Chief Technical Adviser, Battelle Memorial Institute, Columbus, Ohio, U.S.A.)

It is an honour to American metallurgy that the Institute of British Foundrymen, after a succession of four Williams' lectures by eminent representatives of British engineering, metallurgy and physics, has selected an American recorder of metallurgical progress to prepare the fifth lecture. The subject of such a lecture should be in tune with the spirit of the man in whose honour the lectureship is established. Lacking any but second-hand knowledge of the personality of Mr. Williams, I may nevertheless make a reasonable guess at what it is like, since it happens that the Director of Battelle Memorial Institute is another C. E. Williams, and he is a metallurgist of Welsh descent. I have not attempted to make a genealogical investigation to find out if these two C. E. Williamses have common ancestors. I have been able to trace the pedigrees of my English setters, far back to English ancestors among the early Laveracks, Llewellins, Mallwyds, O'Lecks, etc., but tracing the Williams' clan is not so simple.

As I see it, a Welsh foundryman named Williams is likely to be extremely interested in science, in research, and in engineering development, but not at all satisfied with the mere existence of unapplied knowledge in these lines. His most vital interest is likely to be in getting those advances translated into actual practice.

Fostering the Team Spirit

In his presidential address of 1933, Mr. Williams referred to " the team spirit which the Institute of British Foundrymen exhibits and fosters in a very special degree," and further stated: " The Institute is a medium through which the team spirit is linked with other nations." He pointed out that " a spirit of good fellowship and mutual helpfulness creates an atmosphere in which progress can thrive." Hence, I have felt that an account of teamwork in its application to foundry matters, with emphasis upon the " atmosphere " favourable to co-operation and progress, is a fitting tribute to Mr. Williams, and in line with the interests of the Institute of British Foundrymen.

Sir Lawrence Bragg in the 1939 lecture quoted Sir Josiah Stamp as saying: " Knowledge is being mined in laboratories, and buried in periodicals." Research men are accustomed to digging up this " buried " information, but few operating men are so accustomed, nor do they have the time. Moreover, it is a psychological fact that one is more likely to appreciate and to use information that he mines himself, or pays to have mined, so that he has a personal and proprietary interest in it, than he is to appreciate and use second-hand information.

Even if the operating man does find time to read the information buried in technical articles, too often the hints contained in them are not put into practice. They remain merely as interesting abstract statements of what somebody else does, not to be tried in one's own plant until some dire emergency forces a hasty trial as a last resort.

The trouble with industrial research does not lie so much in lack of facilities, in any industrial nation, for development of facts by research, or in means for spreading those facts on the public record. The pages of the transactions of technical societies, and of other technical journals, are nowadays overwhelmingly filled with the results of research. It is in the step of assimilation and utilisation of the results where the big gap occurs. Mere publication does not insure utilisation. One might apply the admonition, "Ye know these things, blessed are ye if ye do them."

You recall the story of the ship off the mouth of the Amazon that was out of water and, in great distress, hailed a passing ship for replenishment. The reply was, " Throw down your bucket where you are." The point of the story is that you have to have a bucket. Published information is as free as water, but it has to be swallowed before it will quench thirst.

Applied Knowledge Counts

In " Metal Progress " for January, 1942, a correspondent asked for information on the use of light sheet steel scrap in the cupola. The reply says to bundle the scrap under high pressure, but concludes: " It is suggested that the services of a professional metallurgist in your district be obtained, one who has had practical experience in foundry production as well as theoretical knowledge. Cast iron is one of the most complex among metals, and no book, article, or letter can do more than point out the general principles upon which to build. There are, for example, many books on medical practices, yet it usually is smart to get a doctor "! In this connection, it is better to have a family doctor, who steadily keeps a watchful eye over you, than to call in a specialist only when you are very ill.

Besides the published facts, there's another reservoir of information. This consists of the little tricks and kinks of saving of labour and materials, or for improvement of quality, that have been worked out in individual plants, but never get recorded in technical literature. Each appears too minor to justify building a technical article around it; moreover, the operating people who devise them are doers, not writers. The total of little tricks, however, can readily add up to a sum sufficient to swing operations from the loss to the profit column in peacetime, or to give a worth-while increase in production in wartime. Swapping information and experience, that is, co-operative attack on the common enemies, ignorance of facts, and ignoring known facts, is extremely logical in theory, but none too easy of accomplishment.

The Personal Approach

The U.S. Department of Agriculture has for many years spent huge sums in investigations for the benefit of the farmer, and has recorded the facts so found in bulletins that he can get for the asking, yet the degree of application was very small. The farmer helped to pay, through his taxes, for the accumulation of facts, but since taxes go for all sorts of purposes, he did not fully realise that he had, himself, paid good money for those facts. In order to get sufficient application of the facts, it was necessary to bring them to the farmer in a more direct and personal way, through "county agents" who visit each farmer, discuss his own operations in the light of his particular and local needs, and point out applications made by his neighbours. An interpreter is required who can both speak the local dialect and understand what he is trying to interpret. In the agricultural field, this direct, personalised approach has brought far better results than the mere distribution of pamphlets, but the method still falls short of the ideal because of its paternalistic aspects. If the farmers of a county, or the progressive fraction thereof, banded together to hire a qualified interpreter and paid him direct, rather than through taxes, his service would be far more appreciated and his suggestions more quickly utilised, than is the case with the governmental set-up.

Swapping Practical Experience

Transferring our thought to any commercial analogy, and particularly to the foundry industry, another bit of basic psychology comes in, especially when it is part of the plan to pass on from one to another the minor operating kinks developed in each shop. This neighbourhood group should not be such close neighbours that they serve the same customers, and hence are active competitors. That factor is of no importance in wartime, with the Government the only purchaser, but it is of major importance in peacetime, and if such a coalition were set up in wartime, it would fall apart in peacetime unless the condition of non-competitiveness has been met.

If the group confines its joint attention to fundamental questions of equal interest to all and does not attempt to deal at all with the swapping of the operational details that go to make up whatever advantage one shop has over another, then such a coalition, even of active competitors, may be workable, but its scope and value are limited. Sometimes it is to the advantage of the more progressive in such a group to help out a newcomer or a weak sister, even though a direct competitor, in the case where the competitor is making so low a quality of product as to give that product a bad name among ultimate consumers, so that assistance on quality control may readily be given, when assistance on reduction of operating costs would be withheld.

Competition Incites Co-operation

Just as attack by a common enemy wipes out pre-existing selfishness and welds a nation together into a normally unattainable degree of co-operativeness, so competition among materials and manufacturing methods incites co-operation among those dealing with a given material by a given method. Welding, forging, even powder metallurgy, are developing under wartime pressure as strong competitors of castings; plastics likewise will offer competition in limited fields. Within the foundry industry, aluminium and magnesium, whose production has been so vastly increased, will be seeking larger use on the basis of reduced cost of those raw materials. Grey iron, malleable iron, cast steel, and the copper-base alloy castings will increasingly be under attack by other materials and other methods of fabrication.

This is fine from the point of view of the general public, for it leads to better and cheaper materials of engineering. But if no defence is put up by bettering and cheapening the old-line foundry products, the shareholders and the workmen of the old-line foundries will not be the outstanding beneficiaries of postwar industrial activities. Under such outside pressure, teamwork, even among active competitors, to preserve their industry as well as the individuals therein, is favoured, since the psychology created by the situation bears some similitude to wartime psychology.

Co-operation among American Metallurgists

A variety of co-operative organisations has grown up in American metallurgy through which the basic problem of the dissemination and application of information from one to another is attacked. Mention should perhaps first be made of the work of sales engineers who travel from one plant to another to lay a technical basis for the sale of a particular alloying element, piece of equipment, sand binder or anything else. Difficulties met in the application of what he has to sell are often smoothed away by tactful suggestions upon operating conditions that are not up to par, and thus handicap the proper use of what he is trying to introduce. Competent engineers, even though they class as salesmen, are welcomed in the plants, and they do succeed in helping a good many customers. Naturally, their advice is limited in scope and may be a bit biased. Anyhow, it is only advice, which the plant has no great incentive to apply.

Most American metallurgical societies originated from the desire of operating men, superintendents, and foremen to get together and exchange information. The Papers presented in the early days dealt with highly practical topics, and the discussion was entered into by the practical men. As time went on, the Papers tended to become more of a theoretical, or at least of a highly advanced, nature, which only the specialist can appreciate, and convention programmes became so crowded that there was no time for adequate discussion. The American Foundrymen's Association has probably succumbed to this trend less than most other societies, but has a constant struggle to maintain a flow of practical Papers.

Value of Discussions by Small Groups

A national society is too large to handle the problem adequately at its annual meetings, so there is an increasing tendency toward local sections and regional meetings where the less formal atmosphere facilitates presentation and discussion of practical topics, but such meetings cover a variety of topics and seldom do more than skim the surface of any one topic.

Smaller organisations of operating men who have like problems fill a need not otherwise met. Outstanding among these is the "Open Hearth Conference," held annually under the auspices of the American Institute of Mining and Metallurgical Engineers. This has been run as a closed corporation, only those directly concerned with making open-hearth furnaces work have been admitted to the conferences. Similar conferences of operators concerned with blast furnaces and raw materials are now held at the same time, since all the problems are related. Naturally, the attention of these conferences is primarily directed to the operation of open hearths making steel ingots, rather than castings, though the latter are not entirely neglected.

A registration fee is charged those who attend, large enough so the expense of the meeting and of printing the record is covered. Although sponsored by the A.I.M.E., it operates quite independently, is self-supporting, and the report of the annual conference is privately distributed, not to the general A.I.M.E. membership. Nor does one need to belong to the A.I.M.E. to join the conference. Operating details, experiences with new refractories, control instruments, etc., are discussed with the greatest freedom, each one feeling that, on the whole, over a period of years, he gets much more from the accumulated experience of others than he himself gives. There was an attendance of 750 at the 1941 conference.

The chances that a kink reported by a practical man, whose ability and common sense are respected, will be tried out after hearing his own first-hand colloquial statement of his experience, are far greater than if the same thing had merely been published in highly dignified language and had been read, instead of heard.

Another group is the Electric Metal Makers' Guild, also a closed corporation, consisting of superintendents, foremen, and electric furnace melters, who similarly exchange experiences. The psychology of the term "Guild" may have much to do with keeping the organisation on a very practical basis.

Steel Castings Groups

The steel-castings industry in the U.S. has several organisations, notably the American Foundrymen's Association, which, of course, deals with steel as well as with all other cast materials, and the Steel Founders' Association, with rather similar aims confined to steel. In both cases, the large number of foundries belonging necessarily makes the activities of a general, rather than a specific nature.

A couple of very interesting small groups existed in the steel-casting industry a few years ago. These were the Electric Steel Founders' Research Group, under the technical direction of the late Major R. A. Bull, and the Steel Castings Development Bureau, under that of the late George Batty, who brought to bear his previous English experience. Both these groups were small, made up of half a dozen or a dozen steel foundries geographically so situated, or specialising in such different types of castings, that they were not active competitors. The basic idea of these groups was that each plant gained experience that could be interchanged through the medium of very frequent visits by the technical director, as well as by periodic meetings of the executive and operating staffs of the constituent plants. Each plant did a considerable amount of research and development work, the expense of which was considered a part of the co-operative arrangement. The results of such investigations were available to all and could be immediately put into operation in the other plants, since the technical director knew just what "bugs" had had to be worked out in the one plant, and could avoid them when another plant was ready to use the information.

That these groups did not formally survive long after the deaths of Bull and Batty is no evidence against the efficiency of such a group. It is evidence that the technical director of any such alliance is the mainspring, and that men of suitable experience and personality for such a task are *rare aves.* They need the background of operating experience that begets confidence in their appraisal of the situation. It costs money to get such men; it takes time of executives and operators to meet with them on their periodic visits. But, just because they are investing money and time, the managements of the member plants are prone to use, rather than pigeon-hole, constructive suggestions.

Grey Iron Groups

In the grey-iron field, the American Foundrymen's Association, and the Gray Iron Founders' Society, deal with problems of the whole industry. The number of local sections of the A.F.A. has grown rapidly, and the Association sponsors several "regional meetings." In these meetings, smaller than the annual convention, operating problems are often discussed.

A smaller group makes up the Meehanite Research Institute, consisting of some 15 licensees of Meehanite patents and presided over by Mr. Oliver Smalley. As there is a similar group in the British Isles, you are familiar with its operations. It appears that much of the strength of the organisation lies in the aid given to member foundries on general operating matters.

Another small group, intentionally kept small, is the Gray Iron Research Institute, in whose formation the psychological factors affecting co-operation were carefully considered. The "specifications" for such a group were: Co-operative attitude of management and operators; geographic location such that all plants may be readily visited, but separated sufficiently so that the plants do not compete in serving the same commercial customers, or, alternately, if located near each other, plant specialisation in type of castings to be such that competition is minimised (the plant capacity ranges from 30 to 1,200 short tons per day); number restricted to about a dozen so that the technical field staff may make at least one two-day visit each month.

Scheme of Co-operative Field Work

The plan calls, first, for application of known facts; second, for finding of new facts specifically needed by the group, *i.e.*, what might be called "selfish research," aimed at actually existing needs and designed for immediate practical application. In operation, a field crew visits the member foundries monthly, watches the foundry operation, particularly as to the working out of suggestions previously made, and talks over that foundry's problems with management and operating staff, meeting jointly. Representatives of other member foundries often go along during these visits in order to pick up details of operation at the plant visited, which the field crew has appraised as applicable to the visitor's foundry.

The field crew consists of a leader, technically trained, and with a long and varied operating experience. The leader is not himself a laboratory research man, but is used to applying the results of laboratory research, and to carrying out plant research and development. He is assisted by several research engineers, technically trained and having had operating experience prior to engaging in research. Needless to say, technical ability in this crew must be coupled with tact, but also with a complete lack of respect for a way of doing things just because they have always been done that way, unless that way happens to be the best way under the existing conditions. It also has to consist of the sort of people who will come in at 2 a.m. to watch the lighting of the cupola, when the field work makes such observations necessary.

Anything and everything relating to improved production, decreased cost, or improved quality is within the scope of the attention of the field crew. Study of waster castings and the causes that led to them, matters of sand control, design of better facilities for mechanical charging, appraisal of available cokes, sorting and sizing scrap, application of "late additions" for production of high strength iron, methods of instrumental control and temperature measurement, ladle linings, sulphur removal, and a thousand and one minor details make up the whole. Great attention is paid to introduction in other member foundries of any little kink that has been proved in any single one.

Battelle Foundry Research

This field work is backed up by research work in the experimental foundry at Battelle Memorial Institute, where problems are studied up to the point where it is justifiable to ~~try~~ out a seeming answer to a member foundry, or whether the studies would too greatly interfere with production, if made in the plant. A great variety of complex "late additions" have thus been given laboratory study so as to simmer down the plant trials to those additions likely to be of most value for the particular type of iron required by the particular type of castings of a particular foundry.

One case was found where late additions were being made to a very heavy casting which froze so slowly that the effect of the addition was dissipated before freezing so that the addition was valueless. Just leaving out the addition saves that foundry the equivalent of £900 per year. Infra-red heating for mould drying has been appraised and its installation advised where applicable.

Humidity control of the blast was studied in the cupola of the experimental laboratory. A commercial installation is under way in a member plant. Instrumental control of the laboratory cupola was worked out with the object of selecting portable equipment for a complete evaluation of all factors of cupola operation. This equipment (Figs. A and B) was in turn taken to each member foundry, and a representative cupola in each put through a complete test. Lack of needed control equipment, failure to replace worn-out equipment, methods of operation falling short of the best, etc., etc., that limited the production of good, hot metal, were thus revealed. The productivity of several foundries has thus been materially improved. In order to facilitate operation, a study of cupola blast control was made in this case by Battelle instead of by the G.I.R.I., but distributed to G.I.R.I. members. In order that this lecture may contain something beside non-technical generalities, a report by Herres and Lorig of this work, hitherto unpublished, is included as a technical supplement. Credit for this belongs to them, not to me.

Need of Communal Briquetting Press

A possibility, not yet utilised by this or other co-operative grey iron groups, that should be helpful in certain localities, is the installation of a briquetting press for grey iron or steel chips, owned jointly by foundries situated near each other, to which the chips from local machine shops are taken for briquetting and from which the briquettes are sent to the cupolas of the owners. The use of briquettes for reclamation of their own machine shop chips has worked out finely in several very large plants whose output is great enough to keep the press working. Many farming communities in the U.S. employ group-owned, tractor-drawn corn harvesters and soya bean harvesters, which are kept busy during the harvesting season. No one small farmer could economically own such a machine, which he would use only a day or two a year. The same principle should apply directly to joint ownership of a briquetting press.

The efficacy of such a campaign for improved operation depends on the face-to-face personal transmission of facts, methods, and experience from one plant to another and from the laboratory to the plant. It accomplishes more than the mere reading of technical articles, or listening to talks at conventions, can ever be expected to do. The desire for application of useful information comes from within the membership, and the presence of that desire is a *sine qua non*—not even government agents can effectively force such aid on unreceptive operators. The fact that the co-operative work comes from the inside and costs money, instead of coming as free advice proffered from outside, is in accordance with sound psychology.

Small Co-ordinating Groups Essential

Any such group must be kept small enough so that the efforts are not spread too thin. The tendency in laying plans for improving practice in an industry is to take in too much territory, so that the effort is thinly spread. Localised, concentrated effort, applied to those portions of the industry that are in the most receptive mood, is more effective. Qualified co-ordinators are few. While others are being trained, the efforts of those few should be exerted where they will have the greatest effect. The advantage of small groups, the "divide and conquer" principle, can hardly be overestimated, and there is no limit to the number of such groups that might be set up; one could make many castings off this pattern.

This type of co-operative reseach, in which the application of what is already known takes precedence over the finding of new facts, and in which the search for new facts is aimed directly at finding out just what one needs to know at the moment, is relatively infrequent. It is very common within single, large industrial organisations that have active research and development groups of their own. Indeed, co-operative work by such a group can be looked at as paralleling what is done by single large firms with several manufacturing branches. Conversely, it can be viewed as a means of putting the technical progress of a number of small plants on a par with that of a large corporation, without shift in financial control.

The type of organisation of the Gray Iron Research Institute represents a practical degree of subdivision in co-operative effort and applies especially to industries with so many members that a coalition of the whole industry is too unwieldy, except for the all-embracing activities of a national technical society, which perforce has to deal almost solely with knowing rather than doing. There is, however, an in-between stage where co-operation within a specialised branch of industry can be effective, even if confined solely to acquiring needed knowledge.

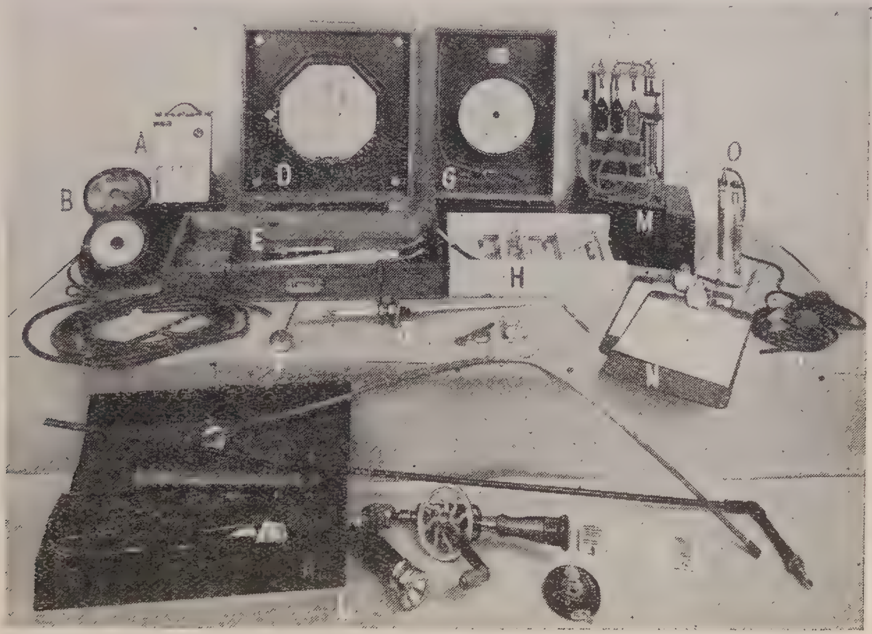

FIG. A.—EQUIPMENT FOR MEASURING AIR DELIVERY TO CUPOLA AND FOR DETERMINING COMPOSITION OF STACK GAS.

A : Recorder for per cent. relative humidity and dry bulb temperature (Friez).—B : Aneroid barometer.—C : Gum rubber tubing for connecting Pitot tube with meters.—D : Flowmeter, 0.2 in. water differential meter to use with Pitot tube.—E : Inclined manometer to use with Pitot tube. Reads in in. water using xylene as fluid.—F : Thermometer for air blast temperature.—G : Recording pressure gauge 0.48 oz./sq. in. Used with Pitot tube if installed in pressure side of blower.—H : Stopcocks and capillaries to use with Pitot tube and manometer.—J : Pitot tube—impact and static openings.—K : Revolution counter and stop watch for checking speed of blowers.—L : Tool box, flashlight, rules, gas sampling pipe and drill for drilling holes in blast pipe to accommodate Pitot tube and thermometer.—M : Orsat apparatus for determining CO , CO, and O .—N : Data boards with watches having sweep second hands.—O : Dwyer rapid CO_2 apparatus.—P : Aspirator and filter for stack gas sample.

Non-Ferrous Bearings Research

A case of this sort occurred several years ago when a half-dozen of the larger makers of bronze bearings, although strong competitors of each other, banded together into "The Non-Ferrous Bearings Research Group" and undertook, with the aid of the Copper and Brass Research Association, to determine more accurately the mechanical properties of the important bronze bearing alloys. Each plant's own test records were correlated with all the others, and where gaps occurred or discrepancies showed up, each alloy was made up in several foundries and tested at Battelle. While it was recognised that the mechanical properties themselves have little necessary relation to the properties upon which bearing performance depends, finding out what ranges of mechanical properties existed in the castings made by each member, was considered worth while. If the practice of one plant on one alloy gave results below the average, that plant could and did examine and improve its practice. This group was set up for the one purpose only, was not planned to be permanent, and disbanded when it had accomplished its object. The results were published.*

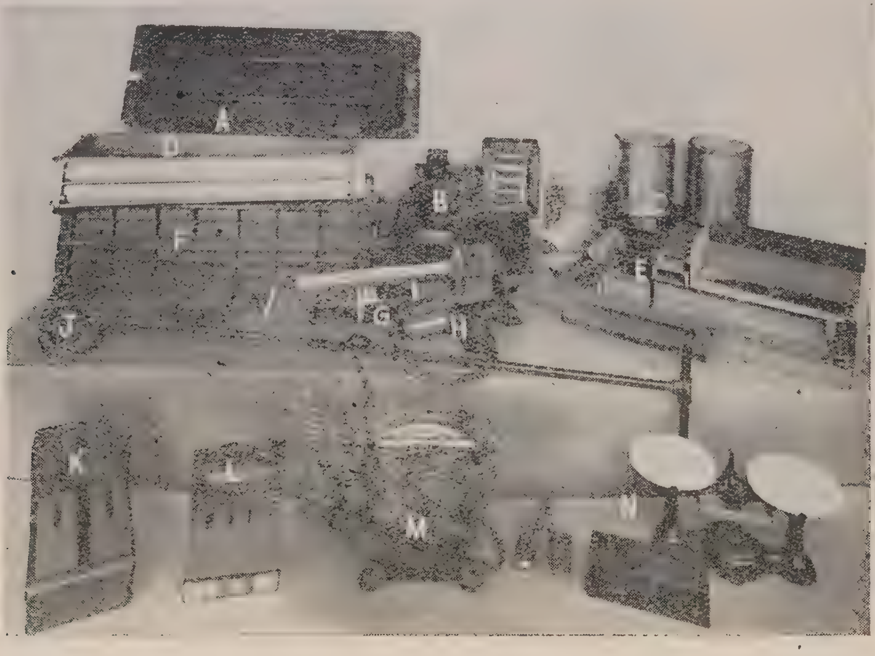

FIG. B.—EQUIPMENT USED FOR TESTING THE IRON.

A: Pattern for two 1.2 in. dia. by 21 in.—B: Core boxes.—C: Alloys for making inoculation tests.—D: Jacket (5 used).—E: Recording dilatometer with cores for determining expansion and contraction of iron while cooling.—F: 20 in. by 28 in. slip flask.—G: "Pyro" optical pyrometer.—H: L. & N. optical pyrometer.—J: Hand ladle for taking iron samples.—K: Water cooled chill and test cores.—L: Chill and core with ½-, ¼-, ⅛-, 1/16-in. sections for chill test.—M: Counter.—N: Balance and weights for weighing alloys.

Another case is that of the Alloy Castings Institute, consisting of some 20 foundries producing more than three-quarters of the output of heat-resistant and corrosion-resistant castings. This group is, in its co-operative effort, not directly concerned with operating practice, but rather with filling the gaps in the needed facts. Members of this Institute are, in general, active competitors, and Institute activities do not extend to any formal exchange of details of operating procedures. The needs felt by each foundry were for more precise information on the properties and applicability of the various more or less standardised compositions called for by the trade, for consistent methods of testing, and for development of alloys with better combinations of properties.

Standard Test-Bar Practice

In the course of the co-operative research, carried out at Battelle Memorial Institute, a standard practice was adopted for making test bars, in the course of which each composition to be studied was made up by several foundries in order to establish the expected commercial range of properties. Incidentally, any foundry whose practice, as shown by this comparison, was not up to average on any particular alloy immediately took steps to improve that practice, just as happened in the case of the bronze bearing alloys. Much work was done to establish the short-time high temperature and the long-time creep properties of the heat-resistant alloys; gaps in the knowledge of corrosion resistance of the corrosion-resistant alloys were filled; means for improving machinability of the latter were found; and a long study of the proper balance of composition in the 25 Cr 12 Ni type of heat-resistant alloy for a combination of strength and retention of ductility in service, proved fruitful. The Patent on the balanced composition has been made available without royalty, for the period of emergency, to non-members. Much of the information that has accumulated has been published.[*]

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* Harder, O. E., and Cole, C. S. "A Study of Six Bearing Bronzes," Trans. A.F.A., Vol. XLI, 1933, pages 314-329.

A by-product, arising from the interest aroused in the corrosion work for the Alloy Castings Institute, was the development by Battelle of a simple method[†] of determining the susceptibility of austenitic corrosion-resistant alloys, to intergranular attack, using the principles of electrolytic polishing.

When, in the pre-war "defence" and lease-lend preparation, it became necessary to limit the use of nickel, the Alloy Castings Institute had a firm enough foundation of facts on properties and applicability of the different grades of heat-resisting alloy, to let it guide its customers to application of lower nickel grades, when such application was justified, and to steer them away from attempted substitution in the limited cases where it was not.

"Non-Ferrous Metals Institute"

Another organisation of interest to the foundry trade is the Non-Ferrous Metals Institute, a group of refiners making secondary copper-alloy ingots, with Dr. G. H. Clamer as a prime mover in its activities, which has long maintained a Research Associate at the National Bureau of Standards for the study of the effect of impurities on such alloys, and which has sought to cut down the number of compositions presented to the trade to the minimum required by the real technical facts. Similar interests tie the makers of secondary aluminium alloy ingot together into the Aluminium Research Institute.

In any co-operative effort it has to be recognised that folks are folks, and that different folks have different ideas. In the face of problems that effect each equally, despite their different ideas, folks can be brought together to pool the ideas and solve the problems. In time of war, anyone with knowledge useful in furthering the war effort is ready and eager to share it, even with his erstwhile most serious competitor, and even though the knowledge would normally be held as a commercial secret. Under dictatorial *régimes*, some approach to such sharing can be forced from above at any time, but that method cannot be applied to individualists of democratic countries in peacetime; nor should it be. The urge to do things in new and better ways is intensified when one may profit thereby, diminished when he may not. Of course, it may be, and often is, good policy to throw secrecy overboard and publicise the advances made, from a strictly commercial attitude, irrespective of altruistic motives. But, on the whole, enlightened self-interest, with private ownership of processes in normal times, pooling under stress of emergency, has led to greater progress than has abstract altruism. We need to combine the driving force of self-interest with a voluntary use of the principle of sharing.

Co-operative Efforts Practicable

Enlightened self-interest leads to the conclusion that if, in a group, each one can exchange a bit of his own knowledge and experience with his follows for two or three bits, each of equal value, everyone is ahead. Co-operative effort among those of like needs has been proved to work, provided a few fundamental principles of human nature are not transgressed. Co-operative research, in practice, is quite as much a matter of psychology as of technology, but experience has shown that foundrymen are sufficiently reasonable creatures, so that co-operation among them is feasible in the U.S.A. Current events are proving beyond a doubt that there is no essential difference between the average man in the British Commonwealth and the average man in the United States; both react in the same way to the same stimuli. Indeed, our British cousins are, in their co-operative attack on broad technical problems of the steel industry, in heterogeneity of steel ingots and allied topics, for example, carrying out a larger and more comprehensive joint investigation than anything attempted in America.

In the foundry field, the British Non-Ferrous Research Association and the British Cast Iron Research Association, with their central laboratories, are producing information of the greatest value, not only in respect to physical metallurgy, but also in respect to foundry practice. No exact analogy to these activities, in which so many different firms co-operate, exist in the U.S., perhaps primarily because of the greater distances at which the plants are located.

"Faith without works is dead"

From the point of view of real progress, it is quite as important to put facts to work, by whatever means best suit the case in hand, as it is to get facts. Research without application is worthless—"Faith without works is dead." The means best suited for application will vary—no previous scheme can be guaranteed to fit a new set of conditions, no matter how well it worked in the previous case. Yet the fact that a plan has worked may well lead us to examine the conditions under which it worked. Perhaps we have only to thicken the bosses on the pattern just a bit in order to use it for another casting.

In *developing* new, fundamental information, the greater the number of co-operators and financial supporters the better, but in *applying* new or old information there seems much virtue in quite small groups, small enough to allow intensive effort. American experience with small groups is so encouraging that it has seemed in order, in discussing teamwork in general, to stress, especially in respect to the foundry industry, the apparent suitability of the small, closely-knit team for easy utilisation of that "team spirit" which Mr. Williams aptly characterised as vital for progress.

APPENDIX I

Explanatory Notes to Figures

Many of the smaller items shown may appear superfluous, but yet all of these items are essential in making the tests. It is undesirable and unsatisfactory to depend on the foundries giving much help in installing the equipment and operating it. Hence, the tests are run by two men of the test crew, one at the cupola spout and the other on the charging platform. Details of the equipment in Figs. A and B are:—

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[*] Harder, O. E. "The Alloy Casting Research Institute Test Block for Heat-Resisting Alloys," Proc. Am. Soc. Test. Materials, Vol. XXXIX 1939, pages 626-636. Gow, J. T. and Harder, O. E. "Balancing the Composition of Cast 25 Cr 12 Ni Type Alloys," Preprint No. 21, Am. Soc. for Metals, 1941, 65 pages. Pray, H., Peoples, R. S., and Fink, F. W. "Addition of Bismuth for Producing Free-Machining Stainless Steels," Preprint No. 29, Am. Soc. Test. Materials, 1941, 10 pages.

[†] Russell, H. W. Pray, H., and Miller, P. D. "Simple Method for Detecting Susceptibility of 18 - 8 Steels to Intergranular Corrosion" Metals Tech., Vol. VIII, September, 1941, 12 pages.

Notes on Fig. A

Friez recorder, with 30-hr. movement recording per cent. relative humidity (hair hygrometer) and dry bulk temperature. The instrument is placed near blower intake.

Flowmeter, a diaphragm type with an 8-hr. clock driven chart, made by Republic Flowmeter Company. This meter is used with the Pitot tube, the impact opening being located at the centre of the blast pipe. From the record obtained, and knowing the density of the air at the point of measurement and the cross-sectional area of the pipe, the air flow can be calculated. It is usually necessary to apply a correction to the centre point velocity. This correction factor is found by measuring the velocity of the air at 10 points across each of two diameters at 90 deg. to each other.

Recording Pressure Gauge, bellows type, made by Bristol Company having an 8-hr. clock-driven chart. If conditions are such that the Pitot tube can be installed on the intake side of the blower, the pressure gauge is connected to the wind box, but if the Pitot tube is installed in the blast pipe, then the pressure gauge is connected to the static connection of the Pitot tube.

Orsat Apparatus (Hayes), used about every half hour for checking CO_2 and O_2.

Dwyer CO_2 Indicator.—This instrument's operation is based on the Orsat principle. Complete CO_2 determinations can be made in less than 1 min.

Barometer.—Placed near blower intake.

Inclined Manometer.—Used with Pitot tube to make velocity survey across blast pipe. Stopcocks and capillaries are necessary to control fluctuation in height of liquid column in manometer. Other equipment shown is self-explanatory.

Notes on Fig. B

Coreboxes for chill test cores, slag samples, recording dilatometer and strainer core for mould. Test bars are cast in green sand. A fireclay bonded synthetic sand having the following properties is used: Moisture, 3 to 4 per cent.; A.F.A. permeability, 90 to 110; green compressive strength, 4.5 to 7 lbs./sq. in.

Recording Dilatometer.—Battelle design on principles adapted from Dawson contraction test apparatus used at Stanton Ironworks, Limited.

Pyrometer.—Two pyrometers are used and frequently checked against each other, as it is unlikely that both of them will lose their calibration at the same time. The "Pyro" is more convenient to use.

Alloys.—75 per cent. ferro-silicon, and two proprietary alloys. No attempt is made in the field survey to evaluate the merits of the alloys, but only to check the response of the iron to inoculation. The results obtained are often quite surprising, due to their effectiveness in improving the properties of one iron and then again having very little effect on some other iron.

Miscellaneous Items.—Chalk for hot marking of test pieces, numbers for marking moulds, hammer for breaking chill test pieces, etc.

TECHNICAL SUPPLEMENT

Cupola Blast Control

By S. A. HERRES* and C. H. LORIG† (January 30, 1942)

The foundry cupola has long produced cast iron under operating conditions which amaze most metallurgists. There are scarcely any limits to the size, quantity, or quality of the scrap, pig-iron, fuel, or flux which have been used. Metal has been produced from almost any design of cupola operated with little or no real attempt at control. An unusually large number of compensating variables tend to produce iron of a kind even when the amounts of charge materials and blast differ widely from plant to plant and from time to time in the same cupola.

When, by chance in uncontrolled cupola melting, certain quantities of metal, coke and air are brought together under favourable conditions, the molten product will have excellent properties. But the use of a given grade of iron from a certain cupola must be governed by minimum, not maximum, properties. To meet more rigid specifications of physical properties, or more difficult casting conditions, some standardisation of the melting operation is required.

A working theory of the cupola must depend on a complete understanding of the reactions taking place during melting. Because of the large number of variables concerned, because the speed of cupola melting is too great to allow many of the possible reactions to proceed to equilibrium, and because our means of observing the procedure of high temperature reactions are rather limited, such a theory has not yet been worked out. However, a study of the chemical and physical properties of the raw materials and products of the cupola allows certain conclusions to be made in the effort to develop the cupola into the precise melting tool we may expect of the future.

Standard Conditions Necessary

To obtain uniform temperature and melting rate in the cupola, it is necessary to standardise: The quantity and quality of the coke and metal charges; the ratio of oxygen in the air blast to carbon in the coke; and the conditions under which the oxygen and carbon are brought together.

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† Supervisor, Foundry Department, Battelle Memorial Institute

The latter condition depends on the amount of surface of coke exposed to air, the velocity of the air, and secondary reactions and catalysts which affect the rate and degree of completion of the reaction between oxygen and carbon. In the foundry, these conditions may be considered constant and neglected when: (1) Coke size, porosity, and chemical analysis are held reasonably constant; in other words, when a satisfactory coke is bought from a dealer who can be relied upon to supply coke with uniform chemical and physical properties. (2) The melting zone and tuyere ratios are held constant, or when the melting zone is patched to correct size after each heat with a grade of refractory which will not burn away excessively, and when the tuyeres are kept free of slag. (3) Charging practice is uniform and no excessively large or very fine material is charged, *i.e.*, there should be no bridging (hang-ups) or channelling of charges. (4) Uniform kind and quality of flux is used, slagging is satisfactory, and no large amount of air escapes through the slag hole.

The coke-to-metal ratio which gives the best results may be found by experiment for a given coke and a certain metal charge. Any change in coke quality or size, or change in metal mix, will require a change in coke ratio for optimum results. For example, an increase of steel in the mix, or the use of large pieces of iron scrap, will require more coke for melting.

Oxygen-to-Carbon Ratio

When all other factors have been taken into account, the efficiency of cupola melting will be largely dependent on the oxygen-to-carbon ratio. Performance of a particular cupola as judged by quality and temperature of metal at spout, melting losses, and economy of coke consumption, is most satisfactory when a certain critical quantity of oxygen is supplied to burn the coke. This quantity may be found by experiment, provided the operator can measure and control the amount of oxygen blown into the cupola for a given amount of coke. To determine it, one should first examine all losses of air in the entire blast system. Any serious and variable loss of air beyond the point of measurement of air blast will invalidate any readings obtained. One should then examine the method of measuring the air. A pressure gauge gives valuable information about the conditions inside the cupola, but is of no use in determining the amount of air blown into the cupola. A differential gauge of the usual Pitot or orifice type will give the relative volume of air, and if correctly installed and calibrated, will come close to the actual cubic feet per minute. There are several air weight-type gauges on the market which compensate for changes in atmospheric temperature and pressure and, excepting the single factor of humidity, give automatically a constant weight of oxygen.

Provided the volume is determined by a differential type of volume meter, a simple correction can be made with the aid of a chart, such as shown in Fig. 1 to obtain a given weight of oxygen per unit time. Temperature and barometer readings are taken at a protected point near the blast intake, or for greater precision, at the point in the system where the blast is measured (the thermometer should be shielded from radiant heat either from the sun or a nearby furnace). Fig. 1 gives the absolute changes in volume resulting from changes in temperature and pressure. For a differential meter with linear calibration (inches of water) where the change in head is directly proportional to the volume change, Fig. 1 can be applied directly. On the other hand, Fig. 1 does not apply directly for a differential meter with a square root scale (cub. ft.). In that case, the change in volume is proportional to the square root of the values appearing on Scale V. To apply the corrections to a differential meter with a square root scale it will be necessary to multiply the indicated volumes by the square root of the per cent. of normal blast obtained from Scale V. A straight-edge placed in line with the temperature reading on Scale T_{db} of Fig. 1 and the barometer reading on Scale B gives the percentage of normal blast on Scale V. The cubic feet per minute of blast desired (for normal conditions) is multiplied by this percentage, or by the square root of this percentage of the volume is measured by a differential meter calibrated in cubic feet, and the blast control regulated to give the volume reading obtained as the product.

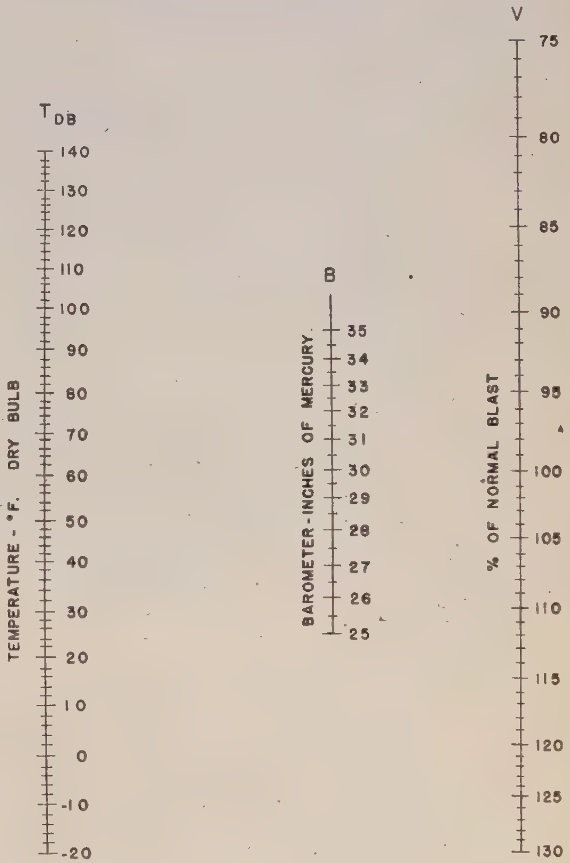

FIG. 1

By always making this correction to normal conditions, the same weight of oxygen per cub. ft. will be blown into the cupola, regardless of conditions of temperature and pressure. Of course, temperature and pressure may vary through the day. How often the blast should be changed depends on the accuracy of blast measurement obtainable and the degree of control desired.

Effect of Moisture on Ratio

The amount of moisture in the air also has an effect on the oxygen-to-carbon ratio. Compared with the effects of temperature and pressure, the influence of moisture is minor. Some foundries, however, are troubled with changes in atmospheric humidity. A few of these have installed air conditioners to ensure a constant moisture content in the air blown into their cupolas.

One foundry corrected for the amount of carbon required to dissociate the moisture in the blast by adding extra coke on days when the humidity was high.* Coke to supply heat for the endothermic reaction and to heat the moisture in the air to reaction temperature was not taken into account. Fig. 3 shows the total amount of coke to compensate for all these factors, also the increase in blast required to compensate for the humidity. The amount of coke per hour, determined by following a vertical line to the bottom of the chart from the intersection of the blast rate (horizontal) and humidity (sloping) lines, should be divided equally over the regular coke charges for one hour. Humidity corrections are made after applying the correction of Fig. 1, and on the basis of the actual volume of blast entering the cupola.

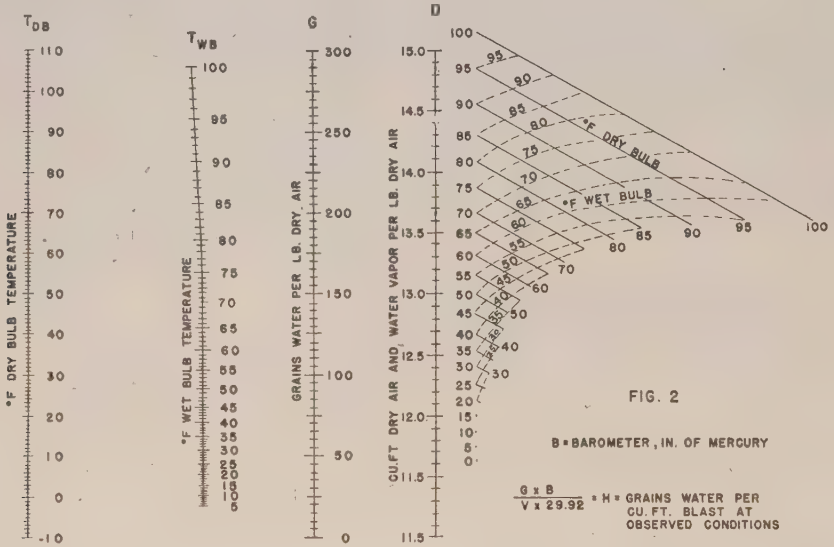

FIG. 2

Before Fig. 3 can be used, the grains of moisture per cub. ft. of blast must be determined and corrected for standard conditions. Humidity is determined by dry bulb (ordinary thermometer) temperature, barometer, and wet-bulb temperature. Wet-bulb temperature may be measured by whirling a sling psychrometer, preferably of the type recommended by the U.S. Weather Bureau, in the vicinity of the blast intake and taking readings. However, the calculation of humidity from these three variables is rather difficult, and the usual form of psychrometric chart is not a great deal of help.

Determination of Humidity

Fig. 2 has been worked out in an attempt to simplify the determination of humidity for blast calculations. A straight-edge placed through the dry-bulb temperature on Scale T_{DB} and the wet-bulb temperature on Scale Twill give a reading on Scale G of the grains of water per lb. of dry air. The straight-edge is then placed through the dry-bulb temperature on Scale T_{DB} and the intersection of the wet-bulb and dry-bulb lines at the right-hand side of the page, and a reading of cub. ft. of air plus water vapour per lb. of dry air is taken on Scale D. Dividing the first reading by the second and making the indicated barometer correction gives the grains of water vapour per cub. ft. of air actually entering the cupola.

The crossing lines at the right-hand side of Fig. 2 are necessary because the volume of a lb. of air varies with the per cent. saturation. Dry bulb (sloping) and wet bulb (dotted) lines intersect at the top of dry bulb line when the two temperatures are equal. This indicates that the air is completely saturated with water vapour. Points down and to the right on dry bulb temperatures show that the air is only partially saturated and will occupy less volume per lb. of dry air. The lower end of dry bulb temperature line is for completely dry air.

Figs. 2 and 3 may also be used in connection with air-weight blast control. Obtain readings on Scales G and D, Fig. 2, as above. Let W = lbs. of air per min. as indicated by air weight meter. Then, W × (1 − G/7000) × D = cub. ft. of air per min. for use in Fig. 3.

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* Dwyer, P. "Cupolas Supply Iron Continuously," The Foundry, November, 1934, pp. 28-31, 72.

Conclusions

Every foundry interested in maintaining quality and economy in connection with cupola melting practice should base air blast supply on a constant weight of oxygen. Supervision and control equipment for making the temperature-pressure correction, as outlined above, will prove an economical investment. Many foundry manuals give instructions for installing home-made volume meters, and the cost of a barometer and thermometer is nominal.

Where a critical type of casting is made, and where intelligent supervision and close control are available, compensation for humidity changes should also be made.

EXAMPLES OF BLAST CORRECTION

I—Hot Summer Day

Observed conditions: 100 deg. F. dry bulb temperature; 85 deg. F. wet bulb temperature; 28 in. of mercury, barometer reading; 10,000 cub. ft. per min. of dry air at standard conditions = base blast figure.*

Refer to Fig. 1.—A straight line through 100 deg. F. on Scale T_{BD} and through 28 in. of mercury on Scale B gives 115 per cent. on Scale V.

10,000 × 115/100 = 11,500 cub. ft. per min.

Refer to Fig. 2.—A straight line through 100 deg. F. on Scale T_{DB} and 85 deg. on F. on Scale T_{WB} gives 160 grains per lb. of dry air on Scale G. A straight line through 100 deg. F. on Scale T_{DB} and the intersection of 100 deg. F. dry bulb (solid line) and 85 deg. F. wet bulb (dotted line) gives 14.65 cub. ft. on Scale D.

$$\frac{160 \times 28}{14.65 \times 29.92} = 10.2 \text{ grains of water per cub. ft. of blast.}$$

Refer to Fig. 3.—Find intersection of 11,500 cub. ft. (horizontal line) and 10.2 grains (sloping line). A vertical line to bottom of chart from this intersection shows that 1,235 lbs. of coke should be added to base coke charges† each hour.

The table on Fig. 3 shows that for 10.2 grains the blast should be increased 10 per cent. (correction based on standard conditions). Correcting this figure to observed conditions by means of the result already obtained from Fig. 1 gives: 10.0 × 115/100 = 11.5 per cent.

11,500 + 11,500 × 11.5/100 = 12,820 cub. ft. per min.

II—Winter Day

Observed conditions: 35 deg. F. dry bulb temperature; 25 deg. F. wet bulb temperature; 30 in. of mercury, barometer reading; 10,000 cub. ft. per min. of dry air at standard conditions = base blast figure.

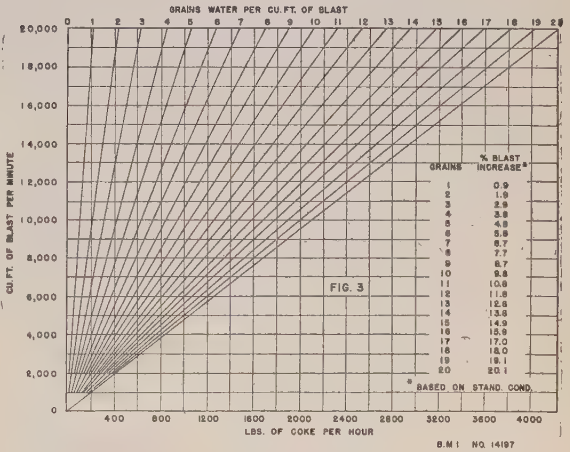
Refer to Fig. 1.—A straight line through 35 deg. F. on Scale T_{DB} and through 30 in. of mercury on Scale B gives 95 per cent. on Scale V.

10,000 × 95/100 = 9,500 cub. ft. per min.

Refer to Fig. 2.—A straight line through 35 deg. F. on Scale T_{DB} and 25 deg. F. on Scale T_{WB} gives 3 grains per lb. of dry air on Scale G. A straight line through 35 deg. F. on Scale T_{DB} and the intersection of 35 deg. F. dry bulb (solid line) and 25 deg. F. wet bulb (dotted line) gives 12.48 cub. ft. on Scale D.

$$\frac{20 \times 30}{12.48 \times 29.92} = 1.6 \text{ grains per cub. ft. of blast.}$$

Refer to Fig. 3.—Find intersection of 9,500 cub. ft. (horizontal line) and 1.6 grains (sloping line). A vertical line to bottom of chart from this intersection shows that 160 lbs. of coke should be added to base coke charges each hour.



GRAINS	% BLAST INCREASE*
1	0.9
2	1.9
3	2.9
4	3.8
5	4.8
6	5.8
7	6.7
8	7.7
9	8.7
10	9.8
11	10.8
12	11.8
13	12.8
14	13.8
15	14.9
16	15.9
17	17.0
18	18.0
19	19.1
20	20.1

* BASED ON STAND. COND.

Fig, 3

The table on Fig. 3 shows that for 1.6 grains the blast should be increased 1.5 per cent. Correcting this figure to observed conditions by means of the result already obtained from Fig. 1 gives: 1.5 × 95/100 = 1.4 per cent.

9,500 + 9,500 × 1.4/100 = 9,630 cub. ft. per min.

APPENDIX

Derivation of Charts

Fig. 1.—The nomogram of temperature, pressure, and volume is based on the simple gas law:—

$$\frac{T_{DB} + 460}{520} \times \frac{29.92}{B} \times 100 = V$$

Where T_{DB} = temperature in deg. F.;
B = barometer in inches of mercury;
V = per cent. of normal blast.

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* If no compensation is made for variations of weight of oxygen in a given volume of air, the cupola efficiency will vary somewhat with atmospheric conditions. The base figure is obtained by observing the blast volume on a day when the cupola performance is particularly good, and figuring backwards from the charts, or the equations in the Appendix, to obtain the equivalent amount of dry air at standard conditions. Changes in base figure should be made whenever the coke or metal, qualities or ratios, are changed. All such changes should be made very gradually, optimum blast volume being chosen on basis of metal temperature, fluidity or castability, etc., melting losses, and coke consumption.

† Base coke charge is obtained by subtracting the coke correction from the actual amount of coke charged on a day when the cupola performance was judged to be good.

To convert barometer reading to any other scale, the following relationship may be used: 29.92 in. of mercury = 760 mm. of mercury = 14.7 lbs. per sq. in. = 1 atmosphere.

Fig. 2.—The nomograms of wet bulb temperature, dry bulb temperature, and humidity are based entirely on data taken from the Psychrometric Charts of the form developed by W. H. Carrier and the Keenan Steam Tables, both widely published in the literature.

Fig. 3.—The relationship between humidity, blast rate, and lbs. of coke per hour was calculated as follows:—

1.—$H_2O + C = CO + H_2$.

2.—18 + 12 = 28 + 2 lbs. of reactants.

3.—57,800 = 29,380 + heat for reaction, Calories (H_2O in gaseous state).

4.—57,800 − 29,380 = 28,420 × 1.8 = 51,200 B.Th.U. = Heat required for dissociation of 18 lbs. of water vapour.

5.—0.9 = 90 per cent. fixed carbon in coke (assumed).

6.—(from 2 and 5) $1 \times \dfrac{12/18}{0.9} = 0.741$ lbs. coke per lb. water vapour to dissociate water vapour.

7.—850 deg. F. = temperature of gas at cupola charging door (assumed).

8.—8.6 B.Th.U. = Mean molal heat capacity of H_2O gas between 850 and 60 deg. F.

9.—13,100 B.Th.U. = Heat per lb. of 90 per cent. C coke burned.

10.—0.50 = Average cupola thermal efficiency under favourable operating conditions. Reliable determinations show that approximately half of the heat of combustion is wasted by being carried away in gases and slag and by being lost through endothermic reactions or by radiation and conduction.

11.—(from 7, 8, 9 and 10)

$$\frac{1 \times (850 - 60) \times 8.6/18}{13{,}100 \times 0.50}$$

= 0.058 lbs. coke per lb. of water vapour to heat water vapour to charging-door temperature.

12.—(from 4, 2, 9 and 10) $\dfrac{1 \times 51{,}200/18}{13{,}100 \times 0.50} = 0.435$ lbs. coke per lb. water vapour to supply heat for endothermic reaction.

13.—(from 3, 11 and 12) 0.741 + 0.058 + 0.435 = 1.234 total lbs. of coke per lb. of water vapour.

14.—1.234/7,000 = 0.000176 total lbs. of coke per grain of water vapour.

15.—0.000176 × cub. ft. of blast per hour × grains H_2O per cub. ft. of blast = lbs. of coke per hour.

Correction of Blast Volume for Humidity

16.—H = Grains of water per cub. ft. of blast.

17.—379 = Cub. ft. per mol. of any gas at 60 deg. F. and 29.92 in. of mercury.

18.—$\dfrac{H \times 379/18}{7{,}000} = 0.003\ H$ = mols. of vapour per mol. of blast.

19.—6.72 = lbs. of O_2 per mol. of dry air.

20.—(1 − 0.003 H) × 6.72 = lbs. of O_2 per mol. of blast.

21.—$\dfrac{6.72 \times 100}{\text{Lbs. of } O_2 \text{ per mol. of blast}}$ = per cent. blast for normal O_2.

22.—Assume 10 per cent. CO_2, by volume, in stack gases (average good practice), then
14.9 per cent. = CO_2 by weight.
15.8 per cent. = CO by weight.
1.82 per cent. = lbs. O_2 per lb. of carbon.

23.—(from 16, 11, 12, 22, 5, 20 and 17)

$$\frac{H/7{,}000 \times (0.058 + 0.435) \times 1.82 \times 0.9 \times 100}{(1 - 0.003\ H) \times 6.72/379}$$

= per cent. blast to burn additional coke.

Adding the blast percentages gives the per cent. of normal blast to correct for humidity. The above calculations are based on standard conditions, and to be absolutely accurate the percentage blast correction should be multiplied by the correction for temperature and barometer, as given in Fig. 1. The assumed figures of charging door temperature, thermal efficiency, per cent. CO_2 in stack gas, and per cent. C in coke are believed to represent average good practice. Where these figures have been determined for a certain cupola, the actual values may be substituted in the above equations and the scales of Fig. 3 changed accordingly.

The Production of Uniform Steel for a Light Castings Foundry

By C. H. KAIN (Member) and L. W. SANDERS (Associate Member)

Introduction

The methods outlined in this Paper are employed in one foundry producing 95 to 100 tons of finished carbon steel castings weekly. Although this is a modest tonnage, it is just double the output for which the plant was originally designed. As the castings are almost entirely light and made in green sand, the floor space must be utilised to the utmost for the production of moulds. A typical week's output was made up of over 5,000 castings totalling 97 tons. The average weight is 38 lbs., with very occasional castings falling in the hundredweight and upward class. This output can only be maintained by careful planning and working to a pre-determined programme. The planning is based on the number of moulds which can be produced in a given time by the equipment installed. The core output is adjusted to suit this, the moulds finished, cored up, and closed as made.

TABLE I.—*Tapping Times.*

Electric furnaces.		Converter.
A.	B.	
2 a.m.	—	1.30 p.m. Soft.
6 a.m.	—	2.15 p.m. Hard.
—	9 a.m.	2.45 p.m. Soft.
10 a.m.	—	3.15 p.m. Soft.
—	1 p.m.	4.0 p.m. Hard.
2 p.m.	—	4.30 p.m. Soft.
6 p.m.	5 p.m.	5.15 p.m. Soft. Delayed to permit 5 p.m., heat from B.
10 p.m.	—	—

It is then necessary to have liquid steel available to pour the moulds, in order that the floor may be cleared and the cycle repeated. This Paper is a description of the steps taken to standardise steel production so that moulds may be poured when ready.

Two processes are in use, the basic electric and the Tropenas. This combination has two great advantages:—

(1) The basic electric can use a wide range of scrap and produce a low-phosphorus/low-sulphur metal, the remelt from which can be used in conjunction with West Coast hematite in the Tropenas to produce steel with a phosphorus and sulphur content comparable with electric steel.

TABLE II.—*Division of Processes.*

Electric furnace.	Tropenas converter.
1. Charging and melting	Melting and desulphurising.
2. Oxidising (converting and slagging off)	Blowing (converting).
3. Reducing (refining) Finishing and tapping.	Finishing and tapping.

(2) The electric furnace can be adjusted to produce a heat of steel at precise intervals (of 4 hrs. in this case), day and night, whilst the Tropenas can produce heats at high speed during the peak casting period, which in most foundries is during the afternoon.

As there are so few castings of large weight, it is not possible to open up the nozzle on a mould of several hundredweights capacity and, if it were possible, it would be undesirable as the standard steel is at much too high a temperature for heavy castings. Hand-shanking from both types of furnaces is practised to a great extent, small moulds being poured in this manner without difficulty. Table I shows the time-table which is worked in the foundry under consideration and each process is considered in three phases, as shown in Table II.

TABLE III.

Electric furnace.	Time.	Converter.	Time.
	a.m.		p.m.
Previous tap complete	9.	End of heating period	12.45
Fettling furnace complete	9.15	Fettling complete	12.57
Charging complete	9.45	Charging complete	1.0
Melting complete	11.45	Blowing complete	1.22
Slagging off complete	11.50	Finishing and recarburizing	1.25
	p.m.		
Finishing complete	12.50	Ready to tap	1.28
Ready to tap	12.55	Tap complete	1.30
Tap complete	1.0		

Table III shows the standard time-table which is aimed at for both processes.

It is not proposed to deal in detail with the chemistry of the processes, as both are fairly well known, but to describe the mechanism of standardised steel production.

PART I—BASIC ELECTRIC PRACTICE

The furnaces in use are of the Electro-metals type with two top electrodes and a conducting hearth. They are rectangular in shape with nut and screw operated tilting and elevating gear. The maximum capacity is 50 cwt. and charging is entirely by hand. The nominal rating is 650 kva. The basis of the process lies in standardisation of the charges, a controlled boil and speed in working.

Charging and Melting

The charge is made up of 45 to 47 cwt. of mixed cold scrap of variable size and consisting of 75 per cent. of scrap and 25 per cent.

of steel turnings. The heavy scrap is charged first, directly under the electrodes, light scrap is charged around the electrodes and in the centre of the furnace, and the steel turnings round the sides. It is found that even slight variation from these proportions causes a considerable lengthening of the melting time; thus an increase to 30 per cent. for the turnings increases the time of a heat by 15 min. The time taken to charge the scrap is between 20 and 30 min., according to the size. The heavier scrap takes longer than the medium variety which can be readily handled by shovels.

The aim is to melt from the bottom upwards, the arc being concentrated on the heavy scrap to form a pool of metal quickly. By this means a constant arc is maintained. Lime is added with the charge, about 75 lb. to the ton being used. This quantity is varied according to the condition of the scrap, dirty or rusty scrap receiving more and high quality material rather less.

Melting is conducted as rapidly as possible with a load of 5,000 amp. at 80 to 85 volts. The time taken to melt a charge of 45 to 47 cwt. from the cold is usually 2 hr. During the melting period care is taken to prevent excessive heat in the centre of the furnace by frequently pushing the charge towards the centre. This prevents over-oxidation or direct attack by the arc on the furnace bottom. Further lime is added from time to time to form slag. When the bath is all clear-melted, the temperature should be just high enough to ensure a liquid slag under normal conditions.

Oxidising and Slagging Off

The temperature is increased as additions of broken ore are made to remove the oxidisable elements. Properly worked, a bath condition arises when a critical temperature is reached and a violent boil takes place. It is essential that this boil be secured. A short and vigorous boil is preferred to a long slow boil, carbon being reduced from approximately 0.38 to 0.09 per cent. in 10 min. This short vigorous boil on a rising temperature gradient appears to be a crucial point in successful practice. Thus, if no boil takes place, the slag is glassy and reflects heat causing the roof to run and making the later formation of a true reducing slag very difficult. Also the absence of a boil appears to be associated with sluggishness in the finished steel.

A long slow boil at constant temperature leaves a bath which is very difficult to kill and which wastes a great deal of time during the finishing period. The essentials are to melt a bath with sufficient carbon (0.35 to 0.45 per cent.) to cause a strong boil, to feed ore slowly and steadily whilst the temperature is raised and not to cause boiling at a low temperature by considerable stirring or rabbling. Immediately the boil has died down and a test shows a soft bath, a sample is sent to the laboratory for phosphorus estimation. The first slag is now poured off and a fresh lime slag put on. Fairly strong oxidising conditions are maintained until the laboratory report is favourable.

At this stage, carbon, silicon, manganese and phosphorus are reduced to a minimum, and are present in approximately the following quantities:—C.C, 0.09; Si, 0.008; Mn, 0.10; and P, 0.015 per cent. There is no reduction of sulphur during the period of melting and oxidising. The slag at this stage is quite black and inclined to brittleness after cooling, containing CaO, 40; FeO, 24; SiO_2, 17; MnO, 4; P_2O_5, 0.9 per cent.; Al_2O_3 remainder.

Oxidation Reactions

The chemical changes which take place during the 2-hr. period of melting and oxidation probably occur in three phases.

(1) *Elimination of Silicon and Manganese.*—The silicon and manganese are oxidised by the presence of iron oxide added in the ore or included with the scale.

(2) *Elimination of Phosphorus.*—The elimination of phosphorus takes place secondary to the oxidation of silicon and manganese. Three definite conditions are necessary for the efficient removal of phosphorus: (1) excess oxygen; (2) very basic slag, and (3) low temperature.

(3) *Elimination of Carbon.*—Similar to silicon and manganese, the elimination of carbon depends upon the amount of iron oxide included in the charge or added in the ore. It is standard practice to take the carbon down to the minimum in order subsequently to recarburise to the hardness desired.

Removal of the Oxidising Slag

After the elimination of the carbon, silicon, manganese and phosphorus, the bath is ready for the removal of the oxidising slag. The removal is carefully supervised as the slag is carrying phosphorus and, under the reducing conditions which follow, this would revert to the metal. Slagging is conducted as follows:—The furnace is slightly tilted and the slag poured or lightly raked off, the load is then taken off and the electrodes raised. A little lime is added to thicken the slag, which greatly facilitates the slagging operation, and care is taken to remove all traces of slag from the sides and banks of the bath.

Skimming is conducted as rapidly as possible in order that heat should not be lost during this period. When the bath is in good condition, the complete removal of slag is accomplished in 7 or 8 min. To the slag-free bath is added 10 lbs. per ton FeSi to quieten the metal, which aids in producing a more uniform recovery when recarburising takes place for higher carbon steel.

Refining, Finishing and Tapping.—In the case of low carbon steels, no carbon is added at this stage, but for higher carbon steels 20 lb. of anthracite duff is thrown into the bath, followed immediately by one-half the total ferro-manganese addition. The bath is now ready to take the refining slag, which consists of 50 lb. of lime, 20 lb. fluorspar, and 7 lbs. coal dust. The load is again introduced and refining begins. The total refining time is approximately 1 hr., half of which is taken in forming the slag and the rest in deoxidising and acquiring heat.

Low power input of 3,500 amp. at 85 volts is used at first, when the slag is quite black in colour, and after about 10 min., as the slag begins to melt, a small amount of FeSi is added which hastens deoxidation. During this period the consistency of the slag is carefully observed, not being allowed to become too viscous or too thin. When the slag is too thick, contact with the metal is not made, and sulphur elimination does not proceed efficiently. If it becomes too thin, serious softening of the roof and walls takes place.

The slag is worked-up to strongly reducing conditions by the addition of lime and coal as required, and at this stage is white in colour, with a strong smell of acetylene denoting the presence of calcium carbide. At this point the power input is increased to 4,000 amp. Spoon samples are taken for general conditions of the steel and the metal quietened by small additions of FeSi. All samples during the refining period are taken with a cold spoon freed from metal and slag before use. The spoon is carefully warmed and slagged before dipping into the bath. Care is used to take the samples from the same position in the bath. When the metal is hot enough and the slag in good condition, a sample is taken for carbon. Final adjustment is made with hematite, and additions of 45 per cent. FeSi and 80 per cent. FeMn are added to bring these elements to the desired quantity. The additions of FeSi and FeMn are calculated from the known weight of metal in the bath.

TABLE IV.—*Electric Steel Tapping Temperatures and Times*

Electric furnace.	Shanking heats.	Bottom pouring heats.
	deg. C.	deg. C.
Tapping temperature	1,650	1,580
Temperature—first pour	1,600	1,560
Temperature —last pour	1,560	1,530
Time pouring	25 min.	20 min.
No. of moulds	80	67
Weight of metal cast	47 cwt.	45 cwt.

The additions are allowed to melt and the bath well rabbled with a bar before a sample is poured into a sand mould. This sample should be quiet and piping. The load is then taken off and the metal allowed to stand 2 or 3 min. before tapping to enable the slag to separate. The slag being highly basic and reducing conditions properly controlled, sulphur is efficiently reduced from 0.050 to 0.014 per cent. Tapping takes place through a tap hole built up with sand outside the door. Although this is a somewhat lengthy procedure, it prevents the slag from running with the metal, and avoids serious variation of carbon content and inclusions of non-metallic material. The metal is tapped into bottom-pouring ladles, which are preheated by gas burners to approximately 800 deg. C., and aluminium is added as the bottom of the ladle becomes well covered. The tapping temperature for shanking steel is in the neighbourhood of 1,650 deg. C., and for direct-pour heats, approximately 1,580 deg. C. Details of pouring times and temperatures are given in Table IV. Unit consumption is at the rate of 869 per ton, inclusive of coke-load and preheating. The temperature readings are taken with a Foster optical pyrometer, looking on to a clean stream of metal, and a correction of 7 per cent. added.

PART II—TROPENAS CONVERTER PRACTICE

Description of Plant and Converter Lining

The equipment in use consists of one 20-cwt. (nominal) Tropenas converter with a positive Rootes blower to furnish air. One Balanced-Blast cupola, 27 in. dia., capable of melting 3 tons of iron per hr., and one 2-ton capacity ladle for receiving the cupola iron for transfer to the converter; one lip pouring ladle from which steel is hand-shanked, and several bottom pouring ladles, all of which are preheated by gas burners. The vessel is nominally of 1 ton capacity, but the first charge is never less than 27 cwt., and this increases as the lining wears. The lining is 8 in. thick, except at the tuyeres side, where it is 11 in. There are five 1⅛ in. dia. tuyeres formed in the rammed lining, for which a proprietary material is used. It is essential to control the moisture content at 8 per cent. during ramming, and to take steps to secure adequate drying and preheating before the first charge. The average life of a lining is 70 blows. The timetable is based upon a standardised converter charge, uniform vessel temperature and controlled blowing conditions. The tuyeres must be perfectly perpendicular to the axis of the vessel, an error of a degree or so prolonging the blow 5 to 8 min. and yielding cold steel.

Melting and Desulphurising

The cupola is fettled and patched each morning, this operation taking roughly 2 hr. The sand bottom is rammed up and a fire started which is allowed to burn through steadily without forced draft, and in about 2 hr. charging begins. As small converters cannot easily be held to size, no patching of the vessel takes place, and the capacity of the vessel increases during the week. Under these conditions a standard cupola charge of constant weight cannot be maintained without seriously modifying the chemical composition of the iron charged to the vessel.

TABLE V.—*Cupola Charge Sheet.*

	No. of cupola charges in converter charge.	Weight of cupola charge.	Total converter charge weight.
		Cwt.	Cwt.
Monday	3	9	27
Tuesday ..	3	9	27
Wednesday ..	4	7	28
Thursday ..	3	10	30
Friday	3	10	30
Saturday ..	4	8	32

To avoid variation of chemical composition in the charge to the converter, the cupola charges are adjusted. Experience has shown that the converter weight increases along the following lines:—At the beginning of the week, 27 cwt. are required, and, as little wear takes place during the first two days, three cupola charges of 9 cwt. to the blow suffice. After the second day the weight increases by 1 cwt. to 28 cwt., and four cupola charges of 7 cwt. are used. For the fourth day the converter weight will have increased to 30 cwt., and three units of 10 cwt. are used.

Table V shows the cupola charge details for the full week. In this manner a uniform composition is obtained without difficulty, as the following figures for six blows testify:

T.C (per cent.), 3.19, 3.03, 3.11, 3.03, 2.95, 3.00
Si (per cent.), 1.41, 1.41, 1.41, 1.35, 1.41, 1.13
(Si reduced)

The charges consist of 70 per cent. steel foundry scrap and 30 per cent. hematite pig-iron, the silicon being adjusted by the use of 45 per cent. FeSi to give a final silicon of 1.4 to 1.50 per cent. The coke used is of the Welsh variety, coke to metal ratio being 1:10. Chalk containing 55.0 per cent. CaO and having a moisture content of 1.96 per cent. is used instead of limestone, 25 per cent. chalk to coke by weight being used. Melting losses despite the sandy nature of the scrap and pig are constant at 5 per cent. Charging takes place immediately the bed has been made up, and as the cupola is hand-charged, the steel is charged first and the pig charged round the sides. Charging is completed in 40 min. The tuyeres of the cupola are set at a height that enables the cupola operator to secure enough metal for the converter in two taps. The taps run at regular intervals of 15 min. with intervals of 5 or 6 min. between each converter charge, during which time the tuyeres are cleaned and the slag-hole made up. Hot iron is secured from the cupola, the temperature being 1,460 deg. C. (optical pyrometer).

Soda ash is used for desulphurisation, 1 lb. of sodium carbonate to 1 cwt. of metal being added to the receiving ladle before tapping. When the metal is tapped a violent reaction occurs, and heavy fumes are given off; after the second tap the reaction occurs again. Sulphur reductions as shown by recent analysis are as follow:—

Cupola..S (per cent.) 0.071, 0.080, 0.068, 0,078, 0.067
Ladle ..S (per cent.) 0.032, 0.037, 0.035, 0.035, 0.029

When the metal has come to rest, the ladle is removed from the cupola pit and the metal skimmed ready to be poured into the converter.

Blowing (Converting)

After desulphurisation, the weight of the metal is checked and poured into the converter, which is in the charging position. The vessel is run up and the level adjusted by the operator. Blowing always takes place on the same angle. A quadrant is attached to the vessel clearly showing the angle, divisions of 5-10-15-20 degrees being shown by a pointer which revolves with the vessel. Blowing takes place on the 15 degree mark. After the level is adjusted the blower is started and blast at 4 lb. per sq. in. pressure introduced, the operator records the time on a board and the blow is on.

A normal blow is as follows: As the blast strikes the bath, light yellow sparks and a small flame, going straight up the hood, proceed from the mouth of the converter. In about 5 min. a reddish brown flame appears directly over the tuyeres. This spreads and develops in length and marks the beginning of the ignition period. At this stage any FeSi that may be considered necessary is added to the converter in lumps. Three minutes after ignition the flame attains its full height, and a vigorous boil ejects a little slag and metal from the mouth of the vessel. At this point the blast pressure is gently reduced to 3 lb. per sq. in. and the vessel "moved up into the wind."

It is not considered good practice to reduce the blast pressure rapidly, as sudden reduction results in the loss of the flame. By the time the boil occurs, the bulk of the silicon and manganese have been oxidised, together with a small amount of iron which pass into the slag as silica, manganese oxide and iron oxide respectively. After reducing the blast the flame remains steady, being "solid" and having length, until about 12 min. after ignition when the carbon flame ascends voluminously and intensely white in colour. As the carbon becomes exhausted the flame becomes streaked and diminishes in length. At this point the converter is turned down, the blow is completed.

The bath at the end of the blow is in a highly oxidised condition containing approximately: C.C, 0.08; Mn, 0.005; and Si, 0.008 per cent. No reduction of sulphur or phosphorus takes place, and actually a slight increase of these elements occurs, owing to the blowing loss which is roughly 8 per cent. The practice of adding FeSi to the converter is only used when metal is to be hand-shanked. It is found that additions of FeSi have a pronounced effect upon the action of the flame, usually two or more boils taking place and, in the closing stages of the blow, it is not unusual for several false drops of the flame to take place before the carbon is finally exhausted. With such inconsistency of flame the possibility of under or over blowing is considerable.

Finishing and Tapping

After the converter is turned down, deoxidation takes place by the addition of 45 per cent. FeSi and 80 per cent. FeMn. The FeSi at the rate of 12 lb. per ton or 0.25 per cent. is added in tins, the slag being pushed away from the metal and the tins thrust into the bath. The FeMn addition is made by dipping the lumps in water and throwing them with force through the mouth of the converter, relying on the wet manganese to explode the covering of slag and penetrate into the metal. The loss of manganese is approximately 30 per cent., 1.40 per cent. being added to finish at 1.0 per cent. The metal is then well rabbled with a bar to work in any manganese that may have been trapped by the slag.

The carbon is adjusted, when necessary, by the use of cupola metal. This method of recarburising is easily adaptable, quick and efficient, hot hand-

Table VI.—*Converter Steel Pouring Temperatures and Times.*

Tropenas converter.	Shanking heats.	Bottom pouring heats.
	deg. C.	deg. C.
Tapping temperature	1,660	1,600
Temperature—first pour	1,630	1,560
Temperature—last pour	1,575	1,530
Time pouring	25 min.	20 min.
No. of moulds	88	75
Weight of metal cast	32 cwt.	30 cwt.

shanks of pre-determined capacity being used. The actual time taken to recarburise a heat is 3 min. After recarburisation, the vessel is turned up to within a few degrees of the blowing position (in order to obtain the maximum movement of the metal) and back again to the pouring position, then rabbled well with a bar to ensure homogeneity. The ladle is brought into the pit and the slag is held back to ensure that the aluminium which is added to the ladle will be taken up by the metal, after which the slag is allowed to run freely. The tapping temperature of converter metal compares favourably with electric furnace metal. Shanking heats are tapped at 1,660 deg. C. and bottom pouring heats at 1,600 deg. C. Table VI gives details of pouring temperatures and times.

APPENDICES

Lining and Preheating of Electric Furnace

Lining.—The side walls and arches of silica bricks are built into position. The bottom is then made up as follows: One in. of ground magnesite is spread over the bottom next to the shell, over which is laid one course of 3-in. magnesite bricks, a further 1 in. of ground magnesite spread over the bricks followed by 2 in. of fine dry dolomite. The actual melting hearth consists of dolomite bonded with tar, rammed into place with pneumatic rammers. The tar is dehydrated (0.5 per cent. max. H_2O) and 8 per cent. by weight of tar to dolomite is used. The tar and dolomite are preheated before mixing but are rammed into the bath cold. The roof is built with silica bricks.

Preheating.—Coke is charged into the furnace and a load of 2,000 to 2,500 amp. at 80 volts is maintained. About 72 hr. heating is necessary to bring the bottom or neutral current into operation in a new furnace. Preliminary heating prior to the week's campaign is similar to the above with the heating time reduced to 6 hr.

Preparation of Converter Vessels

The bottom of the converter vessel is made up of three courses of 3-in. silica bricks. A well-known proprietary material is used for the walls, which are rammed round a wooden former, 27 in. across by 51 in. high, sectional in construction to facilitate removal. The vitrified and burnt material is chipped off the face, leaving about 1½ in. to 3 in. old material round the shell. This is slurried down and the new material rammed into place with pneumatic rammers. The vessel is allowed to stand, drying naturally for as long as possible before being put into work.

Drying and heating are conducted as follows: A small coke fire is started and allowed to burn slowly for 15 hr., additions of coke being made as required. After 15 hr. approximately 5 cwt. of coke is added and air blown in through the tuyeres at 1½ lb. per sq. in. pressure. After blowing once up and down, a further 2 cwt. of coke is added and the blowing repeated. Blowing up and down is maintained for 30 min. in each operation; the vessel is then allowed to hang nose downwards with the tuyere box open. The daily practice is similar. After the nose has been made up, a fire is started at 8 a.m. and alternate blowing up and down the hood takes place at 30-min. intervals. The vessel is then turned down until the coke is withdrawn. Coke consumption increases as the size of the vessel increases and reaches a maximum of 10 cwt.

Physical Properties

Table A details the chemical composition and physical properties of the steels after normalising from 900 to 920 deg. C.

TABLE A.—*Properties of Steel made by the Two Processes.*

Heat No.	Composition, per cent.					Physical properties.			
	C	Si	Mn	S	P	Y.P. Tons per sq. in.	U.S. Tons per sq. in.	El. Per cent.	R.A. Per cent.
			Basic Electric Furnace.						
C. 10970	0·20	0·25	0·85	0·020	0·015	20·8	32·75	39	40
B. 3448	0·41	0·33	1·10	0·020	0·015	24·75	41·55	25	45
			Tropenas Converter.						
F. 9261	0·18	0·22	0·85	0·032	0·037	17·20	32·00	36	56
F. 8349	0·33	0·35	1·10	0·032	0·037	20·00	35·55	24	30

Fluidity

The question of the relative fluidity of converter and basic electric steel is often discussed. It is usually held that converter steel is more fluid than basic electric steel. In the experience of the authors, temperature is by far the strongest factor in fluidity. Temperature readings over a considerable period have shown that converter steel is consistently 40 to 60 deg. C. hotter than electric steel. It is their opinion that with well-made steels the difference in fluidity of the two types of steel at the same temperature is very small.

Non-fluid steels are occasionally encountered and, in the case of electric steel, this is usually found to occur in heats on which the boil has been unsatisfactory. This is often followed by a prolonged period under the final reducing slag. The steel is frequently found to be high in Si and to contain considerable inclusions. In no discussion on fluidity has any reference been found to non-fluid converter steel. Yet this occasionally occurs. It appears to be associated with cold iron in the converter charge and an extended period before the boil begins. A very fluid and sloppy slag high in FeO is formed and it appears that this results in a high proportion of non-metallic inclusions. It would be interesting to know if there is any definite evidence that lack of fluidity is associated with the presence of inclusions.

DISCUSSION

MR. A. G. ROBIETTE congratulated the authors, particularly on the first part of the Paper, which described extremely good practice with rather obsolete equipment. The time cycles operated in American and modern British practice were nearly half the time cycles given in this Paper. Taking the figures given in Table III, he said that in American as well as in modern British practice the charging and melting with the electric furnace could be done within an hour, and the total time was about 2¾ hours instead of four hours as stated in the Table. The effect on the power consumption was that in a 50-cwt. furnace, top charged, the power required was from 680 to 700 units per liquid ton, which meant a saving of 160 or 170 units as compared with the authors' practice. Nothing was said in the Paper about the life of refractories which was generally worse in rapid melting furnaces, but there was a considerable saving in labour costs.

MR. KAIN said the electric furnace equipment in use was admittedly obsolete and it was not claimed that its practice was economical from the modern point of view. The whole object had been to achieve standardisation. The all-important object was to obtain the steel at stated intervals with clockwork regularity, so that at 2 a.m., 6 a.m., and 10 a.m. on, say, Friday there would be 47 cwts. of steel still available to go into the mould. They just had to use the tools which were there. It was interesting to hear that the complete cycle could be reduced to as little as 2¾ hours, and he had to confess that that was rather a surprise to him. The figures of power consumption mentioned, *viz.*, 680 to 700, did not compare over-favourably with the unit consumption in his case of 860 per long ton, because the latter included coke charges and everything else. This figure was taken over a period of 12 months and represented the total power consumption divided by the total steel made, and included all losses during the year. Did Mr. Robiette's figure relate to long or short tons?

Reference to refractory life had been purposely omitted from the Paper because it was a subject of fairly considerable discussion at the moment. The walls of his furnaces were built of silica brick and the life was about 150 heats, which, under the conditions, was very much better than was commonly obtained 6 or 8 years ago. The dolomite consumption for the hearth was 43 lbs. per ton, including the dolomite which was rammed into the hearth and also the dolomite used for fettling. The dolomite used in the hearth was 3 lbs., and the 40 lbs. represented the amount used in fettling after each heat. In other words, the consumption of refractories in repairing the hearth was very much higher than the amount of basic material originally in the bottom.

A Plea for More Science

MR. J. J. SHEEHAN, who said he was interested in converter steel, remarked that ~~up~~ to now the making of steel had been considered an art but the authors had made an effort to convert it from an art to a science. There were, however, certain deficiencies in the Paper, particularly as, in some respects, it still hankered after the art of making steel. In his view there was no art in it to-day. It was definitely a scientific process and should be considered as such. One could see the hankering after the art, particularly in the reference to the blowing. The authors started with a pressure of 4 lbs. and gradually reduced it, for some obscure reason, to 2 lbs. In his view it was possible to produce steel with a constant pressure of 2½ lbs.

Again, there was no reference to the amount of air that was being put in. There was some reference to the pressure and the shape of the flame but too much was left to the judgment of the colour of the flame. Therefore, whilst he regarded the Paper as an effort to take steelmaking from the art stage to the scientific stage, unfortunately the authors had not gone far enough.

There was the question of the amount of air put into a particular mass and the time it took. He agreed entirely with the amount of carbon and silicon the authors had in the composition of their iron, but he did not see the necessity for the addition of any hematite. Although that was very valuable, the authors used 75 per cent. of steel and there was no reason why there should not be 100 per cent. of steel in the charge. There would be considerable economy, especially having regard to hematite iron being in short supply. Therefore, he would like some information as to why the authors used hematite, and also as to the amount of air that was put in after starting to blow at 4 lbs. per sq. in. and gradually dropping to 2 lbs. Why not carry on all the time at a constant pressure of 2½ or 2 lbs.? Further, why had the authors adopted batch melting in the cupola? Why not have continuous melting? There was no reason why there should not be the same charge every day from week to week throughout the year.

Reason for Blast Pressure Reduction

MR. KAIN replied that greatly as he admired Mr. Sheehan's publications on technical subjects, it seemed that on this occasion Mr. Sheehan had not read the Paper with his usual care. Personally he made no attempt to defend steelmaking as an art. Indeed, this Paper was definitely an effort to reduce it to a precision operation. His constant argument with operators in the foundry was that steelmaking, like the mould, etc., was part of the production cycle and must be treated as such. He disclaimed any attempt to retain the "arty" aspect of steelmaking, which he agreed with Mr. Sheehan should be killed.

The blast pressure was reduced from 4 lbs. to 3 lbs.—not to 2 lbs., as stated by Mr. Sheehan—because with the size of vessel being used and the depth of the bath it was found that if the blast was maintained at full pressure there was excessive slopping and projection of the slag through the nose without any increase in the speed of production. It was impossible to reduce the pressure below 3 lbs. because the slag would run back into the tuyere. It was reduced gradually and not suddenly for the reason given very clearly in the Paper. Any sudden alteration in the amount of air going into the vessel entailed an alteration in the flame. If the blast was maintained at maximum pressure on these vessels, which he rather imagined were short for the amount of steel they contained, there were losses from splashing from the vessel. These vessels had a rammed weight of 4½ tons and about 91 tons of steel were obtained from them during the week.

Actually, batch melting was not used in the cupola. Continuous melting was being used, but the cupola charges so adjusted that each charge to the converter consisted of a stated number of complete cupola charges. Owing to the gradual increase in the weight of the charge to the vessel, if the weight of the cupola charge was not varied there would come a time when part of a cupola charge was being taken away to the converter vessel. In that way there were irregularities in the composition. He did not think the practice was utterly bad. Blowing was on a constant coke ratio of 10 to 1 and converting time was between 20 and 22 mins. Precisely 16 heats were now blown complete in 8 hrs. from start to finish, which included all handling, etc., and only 10 mins. were lost for each heat for charging and subsequent removal from the vessel.

Tuyere Standardisation

Unfortunately there were no means available at the moment of obtaining accurate figures of the volume of air going into the vessel, and therefore they could not be given in the Paper. However, it was found to be very important that the tuyeres should be made very accurately. Perhaps that was obvious but very great importance was attached to the correct location of the tuyeres. To obtain this in the lining used, there had been made a very elaborate jig which ensured that the tuyeres were truly perpendicular to the axis of the vessel. That was one of the things done to remove the "arty" aspect, in as much as the operator was not allowed to put the tuyeres in and adjust them as he thought fit. They were put in to a definite gauge and the whole of the operations were so standardised that after the blast had been put on, the whole plant could be left for 9 min. Then the blast had to be reduced because of the intensity of the boil and the danger of slopping. Once the blast had been reduced, there was no more to do until the end of the blow and the operator could go away and return at the end of 19 min.

With regard to the use of hematite, when the present emergency started, the question of going to 100 per cent. steel scrap was seriously considered, using ferro-silicon to make up the composition of the charge. Having no great experience of all-steel scrap charges, he was not anxious, if he could avoid it, to do so, and after negotiations with the Control it was finally decided, in conjunction with them, to adhere to the old practice of 70 per cent. scrap and 30 per cent. hematite because they said it was more economical. If it were absolutely pressed upon him he would be quite prepared to attempt 100 per cent. steel, but his experience a few years ago led him to be rather nervous about it because there had been considerable trouble with cupola wear and cupola erosion and also in disposing of the large volume of slag which was produced with the 100 per cent. steel mix.

All Steel Charges

MR. J. J. SHEEHAN maintained there is absolutely no difficulty in using 100 per cent. steel mix. If there was no difficulty in using 75 per cent. steel mix then there should be no difficulty in going the other 25 per cent. The time of 22 min. for the blow, mentioned by Mr. Kain, he personally considered inefficient, and 12 min. was all that should be taken for the blowing of a 20- to 27-cwt. converter; certainly 12 to 15 min. should be sufficient. With 100 per cent. steel mix the silicon could be kept down and the silicon need not be more than 1 to 1.2 per cent. It was possible to reduce the time of blow in the converter and get the increased efficiency possible with a time of 12 min. as compared with 22 min. The authors had progressed but they had not progressed far enough. There was available a very large amount of steel scrap and it should be used continually, and not necessarily depend upon hematite. These remarks were not so much by way of criticism as by way of stimulation, for the authors had done so well that he would like them to do better.

MR. J. H. COOPER said, whilst admiring what Mr. Sheehan had said, he could not altogether agree with him as to the use of 100 per cent. steel scrap. It was possible but as a working proposition it was not economical. The whole point with the converter was to realise that the process was simply a question of oxidation and de-oxidation. The air, as it passed through the tuyeres, oxidised the metal it came in contact with and then, of course, there was burning of the metal which ignited the silicon and manganese and burned them out, the carbon being oxidised last. He had seen converters with a blowing time of 7 min. only, whilst for others 12 min. was allowed. Within the past week in a new plant, over six charges the blowing time was an average of 23 min., but in these cases the silicon was rather higher than Mr. Kain recommended, *viz.*, 1.5. Providing the bath underneath the tuyeres was not too deep, the blowing time could be reduced to 14 or 15 min.

Seventy-five Per Cent. Scrap Desirable

To get the best results, fluid metal was usually essential. Comparable results were not obtained by the addition of ferro-silicon. One Sheffield firm had been experimenting with 80, 90 and 100 per cent. steel scrap, but it was found that 70 to 80 per cent. gave the best results. He supported the Tropenas process because the metal kept liquid much longer than any other steel, and he was also an advocate of the Stock converter. If really good steel was to be obtained from the Tropenas process it was necessary to start with a pressure of 3 lbs. and drop down to 2 lbs., and, on occasion, when the vessel was not working well and there was a cold charge, the pressure could be reduced to 1 lb. Care must be taken that the metal in the converter did not boil like milk, as it might do, because the vessel was then so full that the metal would run out at the spout. There was much to be said for temperature control and his contention was that if metal with 100 per cent. steel scrap were melted in the cupola and then used in the converter, there was a very much quicker drop in temperature than when using correct composition of metal in the converter.

The ideal was to keep the silicon to about 1.5 or 1.6, and, in the case of small castings, it could sometimes be as much as 2 per cent. There were great advantages in carrying out short period tests, and in the "Foundry Trade Journal" recently it was stated that Messrs. Alexander Baird had carried out blows in 7 or 8 min. with some 200 casts. Other cases were known in which the blowing time was 35 min., thus there was a great difference exhibited. If available he would use hematite up to about 80 per cent. Steel scrap often was unsuitable. It arrived at the works in a rusty condition and involved losses in various directions. Ferro-silicon in the cupola did not always give good results because of the slag produced.

Production Doubled

MR. J. W. GARDOM added his appreciation to the authors for what he termed an exhilarating Paper, and said the particular point which occurred to him was that the authors stated that the time taken to melt a charge of 45 to 47 cwts., from the cold, was usually 2 hrs., but in another part of the Paper they spoke of a charge from the electric furnace coming down in over 4 hrs. It had been stated that the authors' plant was out of date, but surely nobody could imagine the authors were not aware of what was taking place in other parts of the country. Nobody could think the authors were so tied to their own works not to realise that they were working on perhaps obsolete plant, but what speakers seemed to have missed completely was the fact, as stated by Mr. Kain in introducing the Paper, that the output for which the plant was originally designed had been doubled. A great deal was said from time to time about post-war conditions, but no account seemed to be taken of improving the facilities now available and making the most of existing plants. The authors had a certain plant available, and by their methods they had doubled the output from it, which was the all-important point. Nobody could blame the authors for the plant they had, but if outputs could be doubled in a similar manner elsewhere, it would be a great contribution to the war effort. Although he himself had been responsible for spending large sums of money in this country on the erection of new plants, he felt much of the money would have been far better spent encouraging men like the authors to increase the output of their existing plants.

The Chairman (Mr. D. Sharpe) thanked Mr. Gardom for bringing out this point. It was very clearly stated by the authors that their object was to make the best use of the plant they had and to set a time table which would ensure the steel being ready for casting. The details as to whether the cupola converter or the electric furnace were efficient did not quite enter into the subject matter of the Paper. It was a great credit to the authors' concern and their colleagues that they had been able to work out a programme which was as near a continuous casting programme as one could expect to get from a plant of an ancient type such as the authors had. Personally he happened to be one of those who had been presented with a very modern and up-to-date plant which was capable of doing a melt of 4 tons in an hour, but he could bring the lining out of that furnace in 10 mins. A lining could be put in during the week-end and steel be made again on the Monday. In present circumstances it was necessary to leave cost of linings out of account even though they were difficult to get. He wished to offer the authors his congratulations on what they had accomplished. He hoped others would endeavour to emulate what they had done and improve existing plant output in a similar manner instead of having to spend thousands of pounds on the erection of more modern plants.

Mr. J. J. Sheehan pointed out that his criticism had not been of the authors' plant but that they had not worked it properly. He had had a foundry which produced 20 tons of steel castings on an average per week, but it had also been possible to produce a very great deal more in the same place by suitable arrangements, as a matter of interest up to 70 tons per week, and he felt the authors could have done a great deal better if they had used 100 per cent. steel scrap. Mr. Cooper had said it could not be done economically, but what had economics to do with it, at the present moment.

Furnace Technique Queried

Mr. J. F. Gist said that when he first read the Paper he was very interested, but when he looked at the date and found it was the year 1942, he formed the opinion that it was not representative of modern practice. Whilst he wished to be constructive and not destructive in his comments, he felt that the practice outlined by the authors was about 15 years behind the times, as far as electric steel practice was concerned.

At the same time, he agreed that the practice outlined by the authors was quite good for the plant which they had at their disposal. In that respect he also agreed with the sentiments expressed by Mr. Gardom, yet he was bound to say he had had experience of a similar type of furnace, and got his heats out in a very much shorter time than that the authors had mentioned. With Mr. Sheehan he agreed that a very much higher output could be obtained with this particular furnace. On the other hand, if the foundry floor could only take steel every four hours, then the onus was not on his electric furnace to produce it in a quicker time.

There were one or two questions with regard to melting down which he would like to mention, although he had not read the Paper very thoroughly. The authors melted first and then added iron ore to create a "boil" to oxidise out the impurities in the bath. He believed it was current practice, although he stood to be corrected, to make an addition of iron ore with the charge, and that addition was based upon the analysis of the charge, particularly the carbon content, so that as the melt proceeded the bath was slightly on the boil, and the impurities being oxidised out, so that when the bath of steel was melted, and the correct temperature was obtained, the composition of the steel was correct, and the bath ready for slagging. This method saved a considerable amount of time, and prevented the refractories being subject to the arc, and the resulting deleterious effect while the "boil" was taking place.

With regard to carburising by means of anthracite, the authors made an addition of 20 lbs. of anthracite duff, but he would like to know if they had had any experience of carburising by means of pig-iron instead of anthracite, and, if so, had they noticed any increase of fluidity in the resulting steel. The time taken to form a second slag was stated to be 25 mins. Although he was now running a very modern furnace in his foundry, he had also had experience of working an old furnace of the type detailed by the authors, and in both cases he had been able continuously to form a white falling slag within 10 mins. If it was not formed within 10 mins., some very pointed questions were asked. He would like the authors' opinion on this matter.

Controlled Tapping Conditions

With regard to the tapping of steel, it was his procedure with the modern furnace, after carrying out the necessary refining conditions and making the steel to the specification, to thicken up the slag considerably before tapping. The current being switched off when this was done, and the bath held for 3 or 4 mins. The effect of this was for the slag to cake, allowing slag-free steel to enter the ladle, the slag coming out after the last portion of steel. This might not seem very good practice, but he could assure him that he was producing very sound steel by that method, whereas previously there was a little trouble from inclusions in the steel which were not apparent under the microscope, but were seen as small blobs imbedded in the skin of the casting and in the draw holes underneath the feeding heads. These first appeared to be fused sand inclusions, but upon analysis they proved to contain a percentage of manganese silicate. By adopting the practice he had mentioned, he found this trouble was overcome.

Another point with regard to tapping temperature was that he had tried out spoon testing, but could not get consistent results. They seemed to vary considerably with the skill of the operator in taking the spoon samples, therefore he did not regard the results as at all reliable, and that method had been given up. His temperatures were now taken by immersing ½ in. wrought iron rod in the bath of steel for 3 secs., or according to the tapping temperature required. When the amount of rod which is immersed in the bath is completely dissolved off after this time, the steel is considered to be at the correct temperature for tapping. On checking this temperature by means of an optical pyrometer on the stream of metal leaving the furnace, it was found that when the rod dissolved off in three seconds, it is equivalent to a tapping temperature of between 1,580 and 1,600 deg. C. By means of the rod test he found that it was possible consistently to tap out the steel within a variation either way of 10 deg. C.

The authors had a drop in temperature from tapping to pouring the first mould of 20 deg. C. It would be interesting to learn how this was ascertained, because his own experience, using the latest type of optical pyrometer, had been that it was extremely difficult to get anything less than a temperature drop of 60 deg. C. between tapping and pouring the first mould. He would like to know if he used a course of insulating bricks in his ladles.

MR. KAIN, remarking that many of the points mentioned in the discussion would be commented upon in a written reply, said he would go further into the question of the use of 100 per cent. steel scrap mentioned by Mr. Sheehan. As to the time of the blow, he was not interested in the period of 12 mins. because he could not handle the extra quantity of steel so obtained with the plant he was working. Therefore, the question of the reduction of the blowing time did not arise. One of the snags in many foundries was that they struggled all the morning to get the cupola and converter ready and had no steel at all, whilst in the afternoon there was a deluge of steel which was splashed all over the place in handling.

He could not agree with Mr. Cooper that converter steel kept longer than any other steel, if both were properly made. So far as he could see at the moment, provided the steel was well made, the difference in life, fluidity and keeping power was very little indeed. A year or two ago he published some data on this point taken over a period of six months, which showed quite conclusively that the actual keeping power of the steels was practically identical. He would not deal with all the matters of detail mentioned by Mr. Cooper, but the point of the Paper was the necessity for laying down standard conditions and then eliminating the small variables. The idea of having a flat back to the vessel instead of a curved surface in order that the vessel could be turned back so that the metal was lifted on to the bottom of the tuyeres, was one of the "arty" features he had endeavoured to eliminate.

Some very nice remarks had been made by Mr. Gardom. As regards the point that in one part of the Paper it was stated that there was a 2 hours melt, and in another part of the Paper 4 hours was mentioned, the longer period related to melting, refining and finishing.

Working to Schedule

In reply to Mr. Gist, he said it was possible to produce steel in a shorter time than stated in the Paper, and also in a longer time, but the aim had been to arrive at a standard time. If there was a variation in this respect there was difficulty in having the requisite number of moulds ready, and if the time was made shorter then there was also difficulty in disposing of the steel. The whole object was to have the required amount of steel available at the stated times. It was easy to accelerate output if plenty of power was available, which unfortunately was not so in his case, the amount of power available being limited. Mr. Gist was wrong in stating it was the common practice to mix the ore with the charge. It was not possible to control the quality of steel by having oxidising conditions during the melt. That was the whole secret of quality. It was fatal to have unknown oxidising conditions during the melt, and for that reason he melted down to a definite composition and had controlled oxidising conditions after the bath was melted. It was not possible to control the state of oxidisation of the bath during the melt, because as the melt proceeded the temperature was varying and things were rather out of control as far as oxidation was concerned. There was considerably more control if the ore was added after melting, and the control so obtained was essential to successful steel making. He was prepared to defend this at very great length and to produce data to substantiate it.

Minimising Slag Inclusions

The addition of anthracite was not so much for the purpose of carburisation as the removal of excessive oxide. The authors could make white slag in 10 mins., but they did not consider this desirable, as the conditions were not under control. As regards thickening the slag before tapping, Mr. Kain said that for some time he worked exactly to the practice Mr. Gist had outlined, and although the bulk of the slag was held back in that way, finally the conditions were those the authors had tried to avoid, as the last metal and slag ran together. He claimed that tapping from the tap hole produced normal steel freer from inclusions.

He suggested that the cause of the failure of Mr. Gist in regard to his fluidity tests was that he left it to the skill of the operator. The conditions under which the authors took their tests were those laid down by Sanders and not by the furnace operator, and under these conditions it was found that the Ruff test used in an oil sand mould at constant temperature gave very good results. The important point with regard to temperatures was that until there was a really reliable immersion pyrometer available it was not much use talking too definitely about temperature figures. The Schofield-Grace immersion pyrometer was being used with success in 10-ton furnaces, and he did not think the time was far distant when it would be possible to ascertain the actual temperature drop in the ladles. Then it would be seen whether the ladles were properly heated. Considerable research was being carried out on the cooling of liquid steel in ladles, and some results had been published by the Iron and Steel Institute earlier this year. In the case of electric steel a great deal of trouble was undertaken in order to ensure that the ladles were very thoroughly heated for a period of not less than 4 hrs., and in the case of converters 6 hrs., but if there were facilities for going to 8 hrs., results were very much better.

MR. GIST said the reason for adding the ore to the charge was because it had been found with the modern furnace there was considerable erosion of the linings due to refractories being subject to the longer high-voltage arc, and much loss of time in waiting for the boil to finish. However, the ore was not added in a haphazard manner, as Mr. Kain almost suggested, but was previously calculated according to the nature of the scrap charged and its carbon content.

The **CHAIRMAN**, closing the discussion, cordially thanked the authors of the Paper on behalf of the meeting.

WRITTEN CONTRIBUTION

MR. W. H. SALMON, in a written contribution to the Paper, wrote:—

The authors have made a noteworthy contribution to the available information on methods of producing carbon steels for foundry purposes. They are fortunate that they have been able to combine the two processes, basic electric and Tropenas, in one foundry, so that they have no need to rely on outside scrap of unknown or variable sulphur and phosphorus content for the converter process. They are apparently still more fortunate in the freedom from those delays on the electric furnaces which frequently upset the most generous time schedules. The production of a heat regularly every four hours is a great achievement on a hand-charged furnace, considering the delays which may be encountered from broken electrodes, lining and roof troubles, waiting for finishing analysis, and the hundred and one events that arise to upset the programme planned by the foundry to keep pace with mould production. The time saved on analysis alone must make a great difference to the power consumption and cost of steel.

When one is accustomed to a foundry where as many as thirty-four different steel analyses are required in a week's programme, the problem of setting out moulds for heats of two steels only, namely, "hard" and "soft," would be Utopia to our casting team. Probably the factor of simplification of number of steels made and the fact that the authors can cast the rows of moulds in the production lines with either basic electric or Tropenas steel, have had as much to do with the increased output from the foundry floor as the adherence to standard charges in the furnace.

The authors seem to have overcome the adage, "Good steel cannot be made in a hurry," by taking care to make the electric furnace and cupola charges consistent from heat to heat. Having had an opportunity of seeing a number of their steel castings after machining, there is no doubt that the steel they supply to the foundry is excellent for casting purposes.

It is noticed that the authors have omitted the Izod test from the test results printed in Table A in the appendices. It would be of interest to have on record the amount of aluminium added to the ladle (electric and Tropenas) and the corresponding impact tests, particularly if they can give further support to the opinion that there is a critical amount of aluminium addition which produces low ductility and impact resistance, but that further additions result in a great improvement in the Izod test values.

The authors refer to lack of fluidity in certain types of electric furnace and Tropenas heats, in both cases they associate this condition with an unsatisfactory boil leading to a high proportion of non-metallic inclusions. Taylor, Rominski and Briggs (A.F.A. 1941) have shown that quite small percentages of titanium, vanadium and molybdenum (and larger additions of aluminium) seriously impair the fluidity of cast steels. These elements have a higher heat of oxide formation than the elements (silicon, nickel and copper) which improve fluidity, and it is reasonable to assume that because the oxidation products of Ti, V, Mo and Al will be in a fine state of dispersion, they will have an inoculant effect in promoting more rapid freezing. The "considerable proportion of inclusions" reported by the authors in non-fluid heats must be in an extremely fine particle size, because they (the authors) allow ample time for larger particles to rise out of the molten steel, and this cloud of tiny nuclei may be the reason for the lack of fluidity in certain heats. The time they let the electric furnace heats stand with the power off to allow the slag to float out before tapping, the inclusion of a special slag trap in the furnace launder and the fact that they do not reduce the sulphur to the degree required for certain ingot heats, are three factors which will tend to make the fluidity of their basic electric steel comparable with Tropenas steel.

AUTHORS' REPLY

In reply to Mr. W. H. Salmon, Mr. C. H. Kain and Mr. L. W. Sanders wrote:—

In answer to Mr. Salmon, delays due to the causes he mentions very rarely occur. If in Mr. Salmon's works they do occur frequently, allowance should be made for them in the time-cycle and then steps taken to eliminate them.

It cannot be agreed that different compositions of steel should cause difficulty in working to an accelerated time-table. The important thing is to lay down the programme some time ahead. Allowance must be made for variables such as alterations in customer's requirements or specification (past records suggest the amount of allowance necessary), the weight required in each mould, core making, moulding and drying delays. There should then be no serious difficulty in working to an Utopian schedule. Since the Paper was printed it has been necessary to increase output still further and the time-table has been modified as is set out in Table A.

TABLE A.—*Tapping Times* (*Revised*).

Electric Furnaces.		Tropenas Converter.	
"A."	"B."		
2 a.m.	11 p.m.	11.0 a.m.	Soft.
—	3 a.m.	11.30 a.m.	Soft.
6 a.m.	—	12.00 a.m.	Soft.
—	7 a.m.	12.45 p.m.	Hard.
10 a.m.	—	1.30 p.m.	Hard.
—	—	2.15 p.m.	Hard.
2 p.m.	—	2.45 p.m.	Soft.
—	—	3.15 p.m.	Soft.
6 p.m.	—	4.0 p.m.	Hard.
—	—	4.45 p.m.	Hard.
10 p.m.	—	5.15 p.m.	Soft.
—	—	5.45 p.m.	Soft.

This has necessitated a revised moulding programme to provide 6,100 to 6,200 moulds per week, and a revised pouring schedule to accommodate 12 to 16 converter heats per day instead of 8, and 6 electric heats per night instead of 3. This has resulted in a very high output per man-hour and per square foot of area. It is desired to emphasise that the limiting factors in attaining high output are (1) mould producing capacity, (2) melting capacity. All other operations and factors are merely subsidiary to these two.

The aluminium additions to the steels quoted were for "killing" and finishing only and were at the rate of 1½ lbs. Al per ton of steel. Mr. Salmon's suggestion of a critical amount of Al agrees with the authors' experience. No data on this phenomenon or on impact values were given in the Paper as it is proposed to make this the subject of a separate publication.

In general the authors are in full agreement with Mr. Salmon's remarks regarding the effect of inclusions on fluidity.

Paper No. 751

ArmaSteel—Its Manufacture, Control and Applications

By CARL F. JOSEPH*

AMERICAN FOUNDRYMEN'S ASSOCIATION EXCHANGE PAPER

The malleable iron industry is quite frequently referred to as one of the backward industries. Over a period of years, the number of plants producing malleable castings has decreased from 175 to the present of approximately 100. Likewise, the tonnage has dropped from 901,000 tons in 1925, with a Federal Reserve Index of Industrial Production of 104, to 565,000 tons in 1939, with an Index of 106.

This is not a healthy condition for any industry in which to find itself, and upon further investigation the reason is quite readily apparent. The industry, as a whole, has not kept pace with the scientific development of the other iron and steel industries. However, some of the larger units in the industry during the past decade have made use of much of the technical knowledge available, and rapid progress in all branches of the industry has been made. This has resulted in regaining some of its tonnage, and due to more intensive research and development work, better technical control in all phases of the manufacture of castings has been accomplished, resulting in a better and more uniform product.

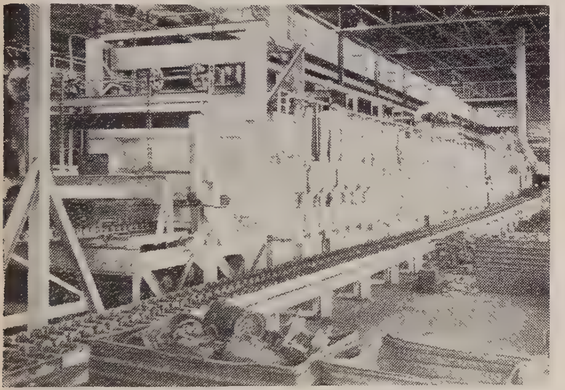

FIG. 1.—ATMOSPHERE-CONTROLLED RADIANT-TUBE GAS-FIRED CONTINUOUS ROLLER RAIL HEAT-TREATING FURNACE.

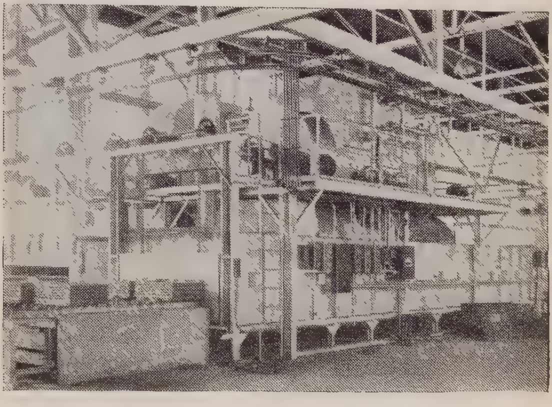

FIG. 2.—ROLLER RAIL RECIRCULATING DRAW FURNACES FOR ARMASTEEL.

National Defence

During 1942, this country will be short some twenty-five million tons of steel. In the interest of national defence it has become increasingly important to reclassify many automotive, refrigerator, tank, machine gun and other parts in order to have sufficient steel and non-ferrous metals to go into those parts which do not offer any replacement possibilities. The question of the proper material to be used to replace many steels, bronzes and aluminium parts is uppermost in the minds of many engineers.

Castings versus Forgings

In recent years there has been a tendency in the motor vehicle field to replace certain forgings with castings. This has gradually followed through in other industries. Many engineers are inclined to put aside the marked improvement in metallurgy as applied to foundry operations which has developed in the past decade. Constant pressure is being brought by the engineers to reduce weight, increase physical properties and cut manufacturing costs. The desire to increase the use of castings has caused the foundryman to venture into hitherto unexploited fields in order to find new uses which have often been considered outside of the range of practical accomplishment.

Selection of Material

The proper material to select for any given purpose is that which will perform the required service at the lowest ultimate cost, provided it can be obtained in the necessary quantity. Intelligent selection and utilisation of materials of construction are important factors, both in the development of new and improved parts, as well as the extension of their use.

Whether the choice be a casting or forging is in many cases a matter of personal opinion. Of course, many engineers are steel minded, and the choice of a casting would be furthest from their consideration, but it is true that stresses, methods of fabrication, possible changes in design, and equipment often favour castings for many parts.

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* Research Metallurgist, Saginaw Malleable Iron Division, General Motors Corporation, Saginaw, Michigan.

ArmaSteel

A versatile metal, known to the industry as ArmaSteel, which in some cases is referred to as a graphitic steel, since the matrix closely resembles that of a spheroidised steel, dates in its development back some twenty years. The earlier researches were given practically no encouragement by engineers, and it has only been during the past five years that any real progress has been made in production of the product.

Chemical and Physical Properties.—This product is made from white cast iron of the following average composition: C, 2.65; Si, 1.35; Mn, 0.40; S, 0.13; and P, 0.05 per cent. The metal is melted in a cupola and refined and superheated in an electric arc furnace. Very close chemical control is followed through on all the raw materials and finished product. Rigid metallurgical control is maintained on all operations. The combined carbon in the matrix gives to the metal properties which compare favourably with those of forgings in the 1,035-1,050 range.

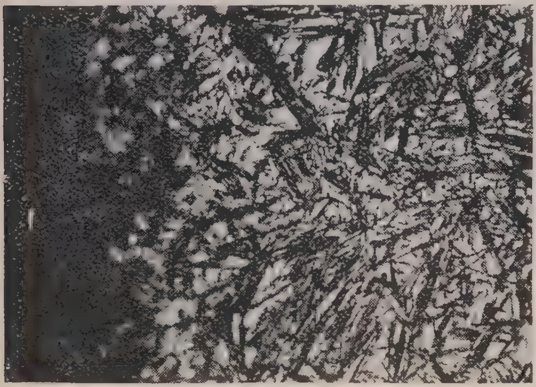


Fig. 3.—Flame-Hardened ArmaSteel Cam, showing Coarse Martensite Structure which offers Poor Resistance to Wear. (× 500.)

Fig. 4.—Flame-Hardened ArmaSteel Cam, showing Fine Martensite Structure, which offers Maximum Resistance to Wear. (× 500.)

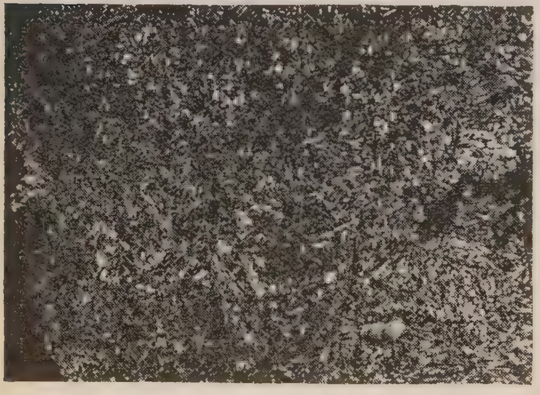


Fig. 5.—Flame-Hardened ArmaSteel Cam, showing Extremely Fine Martensite Structure, which offers Maximum Resistance to Wear. (× 500.)

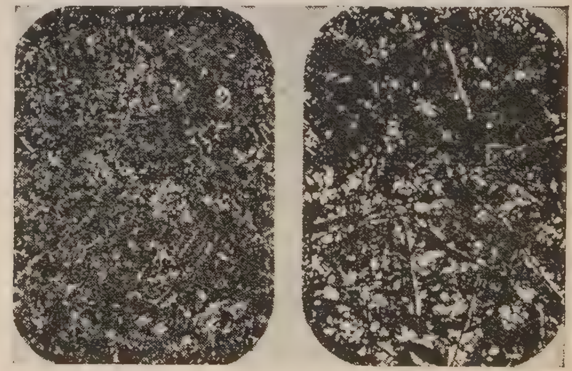


Fig. 6. Fig. 7.

Fig. 6.—10 per cent. Si Pig-iron, showing Steadite, gave Poorly Annealed Castings.
Fig. 7.—10 per cent. Si Pig-iron, Free of Steadite, gave Good Annealed Castings. (Both Etched, × 100.)

Manufacturing Process.—The heat-treatment of the white-iron casting is one of the most important operations in the production of ArmaSteel. The surface structure of the casting must be free from decarburisation; therefore, close control of the furnace atmosphere is necessary. A number of radiant tube furnaces fired with natural gas are used for heat-treating. Fig. 1 shows one of these continuous roller rail type radiant tube furnaces. The castings are brought up to 954 deg. C. and held for the required time to remove all massive carbide, which is around 15 hrs. The castings are cooled to 870 deg. C. and air or oil quenched. This is followed by a tempering treatment to improve machinability and control physical properties. The time and temperature vary with the

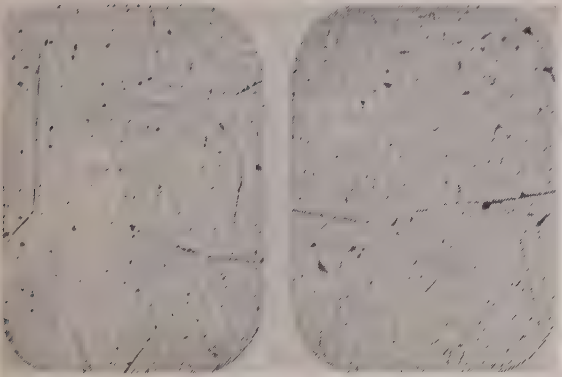


Fig. 8. Fig. 9.

Figs. 8 and 9.—10 per cent. Si Pig-iron, Unetched, × 100. Showing Small Graphite Flakes in Fig. 8, and Medium Graphite Flakes in Fig. 9.

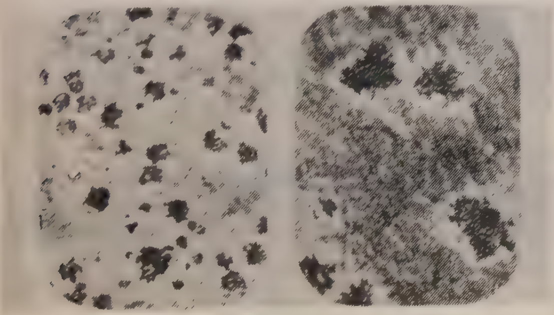


Fig. 12. Fig. 13.

Figs. 12 and 13.—ArmaSteel, 4 per cent. Nital Etch, × 100, showing Effect of Small-Flake (Fig. 12) and Medium-Flake (Fig. 13) Graphite Pig-iron used in Production.

design of the casting and Brinell hardness requirements. A tempering temperature of 675 deg. C. for 4 to 6 hrs. will produce castings of approximately 197 to 241 Brinell, and for 6 to 8 hrs. 163 to 207 Brinell hardness. Fig. 2 shows two of the recirculating temporary furnaces used in malleablising ArmaSteel.

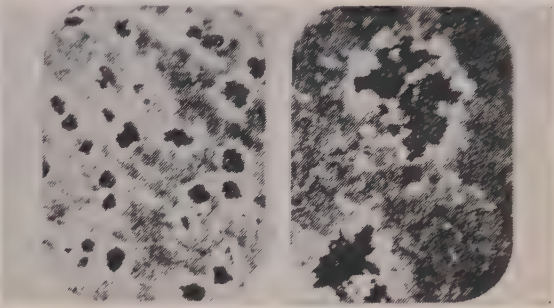


Fig. 10. Fig. 11.

Figs. 10 and 11.—ArmaSteel, 4 per cent. Nital Etch, × 100, showing Effect of Small-Flake (Fig. 10) and Medium-Flake (Fig. 11) Graphite Pig-iron used in Production.

Control of Product

The practical approach to the control of uniformity of the product must be based upon adequate statistical information regarding the product itself and the variables of its manufacture. To this end more or less elaborate statistical systems are employed to record melting and raw material variation and correlate these factors with quality and uniformity. By a study of the records, the metallurgical practice in the plant will fall into a narrower groove of smaller deviations, with the ultimate result of lower rejections and higher quality.

The Metallurgist's Utopia.—The metallurgist's Utopia is a run of metal, producing parts with uniform properties, which will always respond to

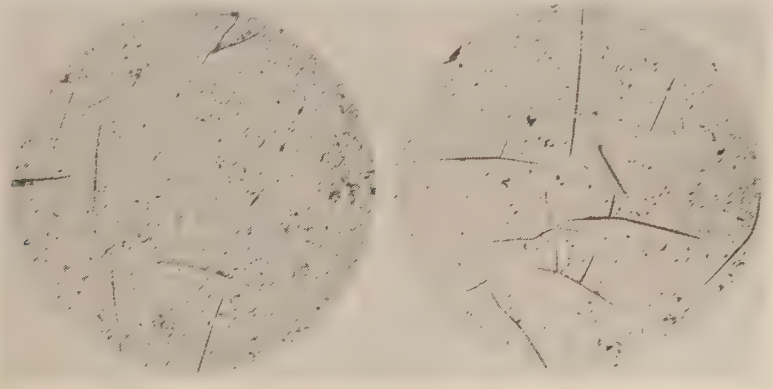


Fig. 14. Fig. 15.

Figs. 14 and 15.—10 per cent. Si Pig-iron, Unetched, × 100, Both Completely Cooled by Water Spray. Sections of Pig-iron from First Portion of Cast (Fig. 14) and Last Portion of Cast (Fig. 15).

the same heat-treatment, machining, hardening and wear qualities, showing normal behaviour and no rejections. In the same Utopia it will be necessary to have definitely uniform raw materials. The supply of the latter is becoming more difficult, since specialisation is placing a constantly growing burden upon blast furnaces, coke ovens and steel manufacturers.

Manufacturing Process

Specifications and Tests.—The application of ArmaSteel in the motor vehicle and allied industries is mainly in the replacement of drop forged steel parts, such as crankshafts, camshafts, rocker arms, shifter yokes, gears, etc. The metallurgist pins down the steelworks to very exacting specifications as to the steel used for these parts. To mention

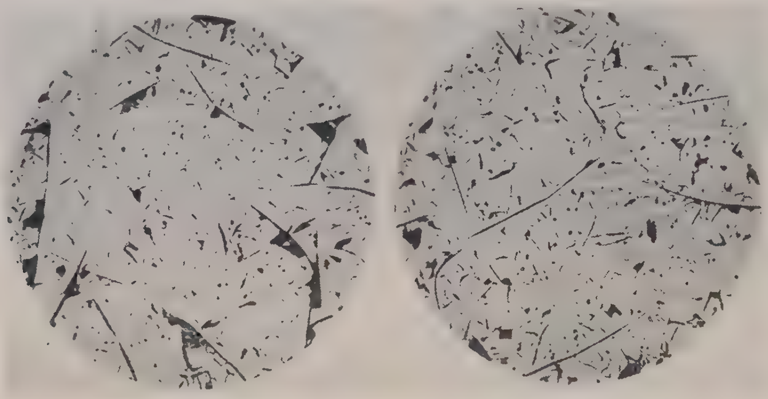
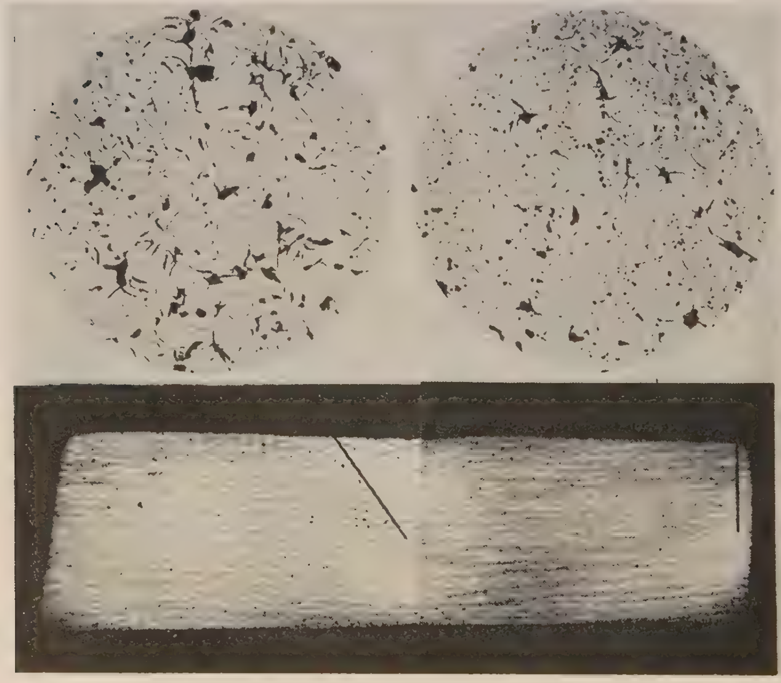


Fig. 16. Fig. 17.

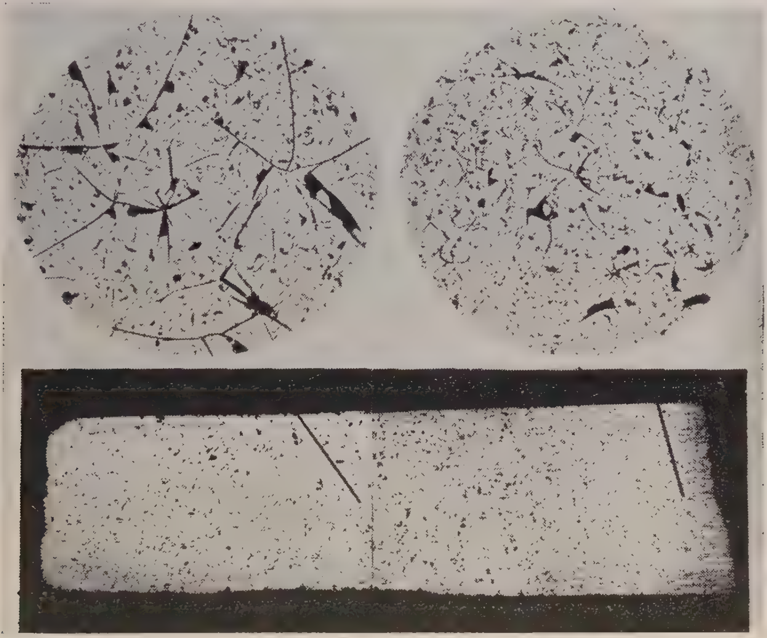
Figs. 16 and 17.—10 per cent. Si Pig-iron, Unetched, × 100, showing Section of Pig-iron from Middle Portion of Cast when only half way through Cooling Spray in Fig. 16 and when Air Cooled in Fig. 17.



Figs. 18, 19 and 20.—10 per cent. Si Pig-iron, Cast in Copper Mould, No Lime Wash, showing Structure at Centre of Pig (Top Left) and Near Bottom Surface (Top Right), Both Unetched, × 100. Fig. 20 (Below), Unetched, × 3, shows Surface Fine Ground but not Polished.

a few of these tests: chemical analysis, grain size, slag inclusion, abnormality, hardenability, machinability, and others. These factors are primarily controlled in the melting of the steel at the steelworks and require highly skilled technical help.

The foundry industry is following the steel industry in employing increasing numbers of technical men. This is bound to reflect in development of new products, and should be productive of some remarkable results in the not too distant future. ArmaSteel responds to heat-treatment very similarly to steel; therefore, it is only reasonable to believe that this new metal will be subjected to numerous tests and specifications, as its use is further extended.



Figs. 21, 22 and 23.—10 per cent. Si Pig-iron, Cast in Old Steel Mould, Limewashed, showing Structure at Centre of Pig (Top Left) and Near Bottom Surface (Top Right), Both Unetched, × 100. Fig. 23 (Below), Unetched, × 3, shows Surface Fine Ground, but not Polished.

The engineer and foundryman are obliged to compromise on a particular composition and heat-treatment of metal that will give a certain hardness and will have the maximum strength, together with adequate machinability for the particular job. The machinability of the metal depends upon the metallographic structure, which is influenced to a marked degree by the solidification rate of the metal and cooling rate thereafter.

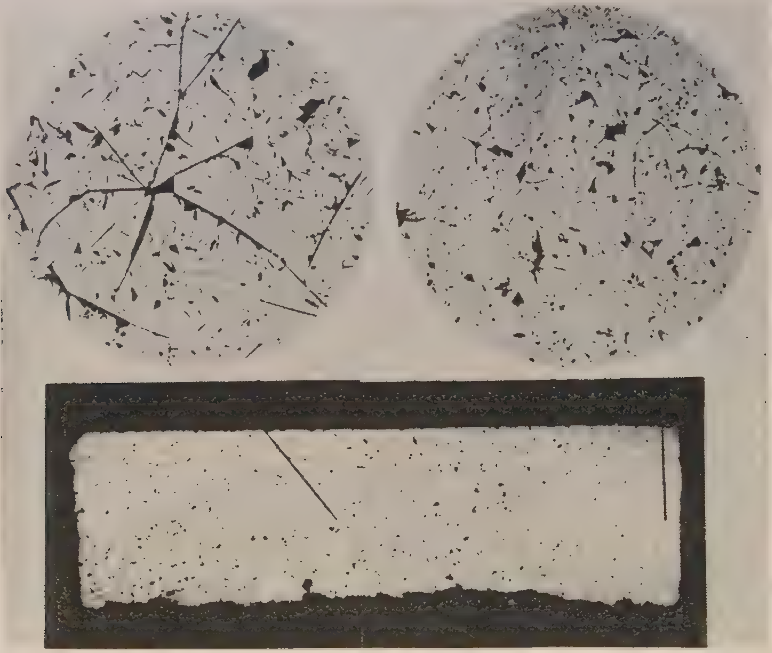
Grinding v. Machining

The development of the art of grinding, in partial replacement of machining, opened the industrial door to hard ArmaSteel for many applications, which had been closed before for the simple reason that they were too hard to be machined. A good example is the flame-hardened ArmaSteel camshaft of to-day. The hardened cams are rough and finish ground instead of rough machined as in the past.

An interesting sidelight on the flame-hardening cam structure reveals that temperature control of the surface to be hardened is extremely important. Wear tests on cams of the same Rockwell "C" hardness reveals that the finest grain structure shows the minimum wear; it is, therefore, desirable to obtain the finest structure possible, which is accomplished by heating to the lowest temperature necessary to produce the depth desired and degree of hardness. Figs. 3, 4 and 5 show cam microstructures at 500 diameters of a badly worn cam (very coarse) and two cams of no wear. The latter shows an extremely fine martensitic structure, which gives maximum resistance to wear, erosion and abrasion.

Personnel Angle

The personnel angle enters into the control of any product, and in particular in the development of a new product which is expanding its field to cover and replace a material which in the past has given satisfactory service. Also, when replacing forgings, it must be remembered that many years, undoubtedly, were spent on certain parts before the present high quality was obtained, and to overcome this handicap the training of personnel to produce a new product is of major importance. There are two ways this problem must be approached—one is to continue to train personnel along technical lines in the development of an attitude of responsibility and teamwork throughout the organisation—and the other is in research of the basic principles underlying the metallurgical aspects of iron-making methods, including new aids in the control of the process and new kinds of equipment needed to do a better job. "Just good enough to pass" is no longer the attitude to take. "As good as possible" is what must be drilled into the workmen and foremen alike. To strive for higher quality will produce results both in increased business and lowering of costs. ArmaSteel must receive the attention of that given to quality material. It must be processed in smaller batches to insure uniformity and exactness of control.



Figs. 24, 25 and 26.—10 per cent. Si Pig-iron, Cast in New Steel Mould, Limewashed, showing Structure at Centre of Pig (Top Left) and Near Bottom Surface (Top Right), Both Unetched, × 100. Fig. 26 (Below), Unetched, × 3, shows Surface Fine Ground, but not Polished.

Melting Equipment and Procedure

The melting equipment used by various manufacturers in the production of sorbitic or graphitic steels is not as important as the raw materials going into the charge. It is true that the chemical composition of the metal from the various melting processes will show a wide variance, but this to a great extent is due to the nature of the charge used and the amount of oxidation of the elements in the melting operation. Most manufacturers use pig-iron and steel in the charge. Those using the duplex process use cupolas as the melting medium, and coke plays an important role in the successful operation of the cupola.

Pig-iron

At the Saginaw plant silvery pig-iron and coke are two of the principal raw materials affecting the properties of the product, and both are carefully controlled. Heredity is common to both pig-iron and coke, and many bad experiences in the past have been traced directly to these two materials. Close control of both of these materials at the source is maintained. Chart I illustrates the data obtained at the blast furnace on every run of silvery pig-iron. No changes in blast furnace raw materials or operations are made without consulting the foundry. Naturally chemical composition must be relied upon in making up the cupola charge, but is only a means of control in the successful operation of the cupola, and offers very little in the way of solving the many metal troubles experienced in the foundry. Even with close chemical control in the foundry, there are chances for variation in the finished product which can often be traced back to the ores or fuel used in the blast furnace burden or the blast furnace practice. In general, the pig-iron producer has no difficulty in meeting chemical specifications for carbon, silicon, manganese, sulphur and phosphorus. Even alloys are absent to a degree which might cause any trouble. Microscopic examination of the pig-iron is a routine test of the greatest importance. From the annealability angle, the microstructure of the pig-iron should reveal little or no steadite. In the past this structure has definitely shown that the iron will anneal with difficulty when large amounts of steadite are present.*

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* A.F.A. Transactions. Vol. 40, 1932. High-Silicon Pig-Iron for Malleable Manufacture. A. L. Boegehold—Carl F. Joseph.

The accompanying micrographs, Figs. 6 and 7, show the amount of steadite present in good and troublesome pig-iron. Steadite in even small amounts is undesirable in pig-iron to produce castings for short-cycle malleablising.

Graphite Size as Influenced by Pig-iron

Graphite size in the pig-iron has a marked influence on the properties of the resultant castings. Since ArmaSteel parts in many cases are highly polished, it is extremely important that the castings have small temper-carbon spots. Large carbon spots adversely affect the machinability. Therefore, in order to produce the most satisfactory castings as regards surface finish and machinability, a study of the graphite size in pig-iron is of utmost importance, as it directly affects the carbon spots of the casting. As mentioned before, ores, coke and blast-furnace practice affect the properties of the pig-iron, and this is particularly true regarding size of graphite in pig-iron. Figs. 8 and 9 represent small and medium graphite flakes respectively in two different pigs (micrographs taken from centre of pig). Figs. 10 and 11 represent ArmaSteel produced from pig-iron in Figs. 8 and 9 respectively, tempered to a Brinell of 207. Figs. 12 and 13 represent ArmaSteel produced from pig-iron in Figs. 8 and 9 respectively, tempered to a Brinell of 170. Note the large variation in size of the temper carbon in the ArmaSteel produced by each of the two pig-irons of like chemical analysis. Large graphite in the pig-iron is carried through the melting operation to the malleablised structure of the annealed casting.

Pig-iron Casting Practice v. Graphite Size

The following micrographs indicate the effect on rate of cooling of the pig-iron through and after solidifying in the mould (all micrographs were taken from centre of pig × 100). Fig. 14 is from the first portion of the cast completely cooled through the water spray; Fig. 15, the last portion of the cast completely cooled through the water spray; Fig. 16, from the middle of the cast removed when half-way through the cooling spray; and Fig. 17, from the middle of the cast, air-cooled. The last two micrographs show larger graphite flakes. There is a definite tendency to coarsen the primary graphite on more slowly cooling through the solidification range. The rate of cooling after solidification has no effect on the coarseness of the graphite. Some work has been done to determine the effect of graphite size in pig-iron produced by casting metal into both copper and steel moulds

---

CHART NO. 1.

Quality of Iron as Affected by Blast Furnace Practice: Pig Iron—Blast Furnace Data.

1.—Furnace No. .... Location ....
2.—Superintendent .... Date Produced ....
3.—Composition of Ores:

Name—						
Fe	....	....	....	....	....	....
P	....	....	....	....	....	....
SiO_2	....	....	....	....	....	....
Al_2O_3	....	....	....	....	....	....
CaO	....	....	....	....	....	....
MgO	....	....	....	....	....	....
Mn	....	....	....	....	....	....
Per cent.	....	....	....	....	....	....
Pounds	....	....	....	....	....	....

4.—Coke Charge ....lb. Coal Charge ....lb.
5.—Rounds per day ....
6.—Kinds of Coke—
  1. Shatter Test ....
  2. True Sp. Gr. ....
  3. App. Sp. Gr. ....
  4. Porosity....................

Analysis—
  Fixed Carbon ....
  Vol. Hydrocarbons.. ....
  Ash ....
  Sulphur ....
  Water ....

7.—Burning Characteristics of Coke:
  1. Av. Temp. Rise ....
  2. Av. Time for 250° Temp. Rise ....
  3. Ignition Temp. ....

8.—Kind of Coal ....

Analysis—
  Fixed Carbon ....
  Vol. Hydrocarbons ....
  Ash ....
  Sulphur ....
  Water ....

9.—Limestone Source ....
  Analysis—
    Ca Co_3 .... CaO ....
    Mg Co_3 .... MgO................
    Oxide ....
    SiO_2................
    ....

Lbs. of limestone per round ....
Lbs. of limestone per ton..................

Chart No. 1—*continued.*

10.—Blast Temp. .... Max. .... Min. .... Cycle ....
11.—Blast Pressure .... Av. /sq. in. .... Max. .... Min. ....
12.—Air per minute .... cub. ft. .... lb.
13.—Fuel burned per hour .... lb. .... /sq. in. area at max. dia. ....
14.—Pounds of air per pound of fuel .... Air per lb. of carbon ....
15.—Blast velocity through tuyeres .... ft. per min.
16.—Composition of top gases .... per cent. CO .... per cent. CO_2 ....per cent. H
.... per cent. H***
17.—Temp. of top gases ....
18.—Burden per hour. .... lb. .... /sq. ft. area at max. dia. ....
19.—Composition of slag .... (flushing slag)
SiO_2 ....
Al_2O_3 .... Appearance of slag ....
20.—Weight of iron produced per hour .... lb.
Weight per sq. ft. area at max. dia. per hour .... lb.
21.—Depth of metal in hearth at tapping .... ft.
22.—Casting Temp. .... max.
.... min.
.... Av.
23.—Time between casts .... hrs.
24.—Dimensions of furnace:
1. Stock line to tuyeres .... ft. .... in.
2. Tuyere level to hearth .... ft. .... in.
3. Size and number of tuyeres ....
4. Iron notch to cinder notch .... ft. .... in.
5. Dia. of hearth .... ft. .... in.
6. Dia. at top of both .... ft. .... in.
7. Cubical contents of furnace .... cub. ft.
25.—Number of stoves .... In use .... heating up ....
26.—Chemical Analysis:

Average of Five Pigs.

T.C	C.C	Si	Mn	S	P
....	....	....	....	....	....

27.—Atmospheric temperature, deg. F. .... max.
.... min.
.... Av.
28.—Barometric pressure .... in. Hg
29.—Humidity .... Grs. per cub. ft.

Figs. 18, 19 and 20 show pig-iron cast in a copper mould, using no lime wash; Figs. 21, 22 and 23 show pig-iron cast in an old steel mould, using lime wash; Figs. 24, 25 and 26 show pig-iron cast into a new steel mould, using lime wash; and Fig. 27 is a photograph of polished sections of high-silicon pig-iron cast in an uncoated copper mould and in a coated steel mould. The fact that pig-iron cast in a copper mould shows a sounder iron, in which the graphite flakes are much finer than the same iron poured into a steel mould, is an indication of better casting practice, and is a step in the right direction. The casting of smaller and thinner pigs produces a somewhat finer graphite size.

Figs. 28 and 29 show near the surface and centre of a 38- to 42-lb. pig, which represents a better graphite size than that of a heavier pig. The pig-iron producer will be called upon more and more in the future to help the foundryman solve some of his troubles, and graphite size of pig-iron is only one of them.

Coke

In the duplex process, in which the cupola is used as the melting medium, coke plays a major rôle in the production of high quality metal. Many foundrymen prefer poor melting stock to poor coke. That only proves that good coke is almost a necessity in the successful operation of the cupola. In the classification of coke, the author likes to refer to "slow" and "fast" burning coke. The method of determination of burning rates is described in A.F.A. Transactions.*

Northern cokes, produced from coals mined in the northern part of the United States, are fast burning, and produce higher carbon metal at the cupola spout, usually at a lower temperature than that obtained from southern coke, produced from coals mined in and around the State of Alabama, which is slow burning and produces a low carbon metal. Regardless of the coke source, it is desirable to have uniform sized coke, free from green ends and porosity. There is some question among foundrymen regarding the size of coke. Some prefer large chunks (6 to 8 in. across), others like small pieces (2 to 3 in. across). The diameter of the cupola has considerable bearing on the most desirable size. In the operation of an 8 ft. 6 in.

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* A.F.A. Transactions. Vol. 37, 1929. Quality of Pig-Iron and Castings as Affected by Blast Furnace Practice. A. L. Boegehold.

diameter cupola, coke the size of two fists (about 4 to 5 in. across) is giving satisfactory results.

Many bad experiences in the past in maintaining close carbon control on cupola metal has prompted much investigation on the major sources of carbon, which is coke. The metallurgical coke used in the production of low carbon cupola metal performs two functions. First, it supplies the heat to melt the iron and steel charge, and secondly, it carburises the charge, raising the carbon from an average of 1.40 per cent. to 2.60 per cent. To maintain the molten metal to within the desired 10 point range, one must have a coke which will meet rigid specifications.

Close control must be maintained at all times and any changes immediately relayed to the foundry. Sometimes minor changes in the coals used in the coal mix have a major influence on the properties of the metal. In order to maintain close control of the coke the management requires periodic reports from the coke ovens covering all important points in their operation and raw materials used. No changes are made without first advising the foundry. Chart II is a sample covering the coal and coke data furnished periodically to the metallurgical department.

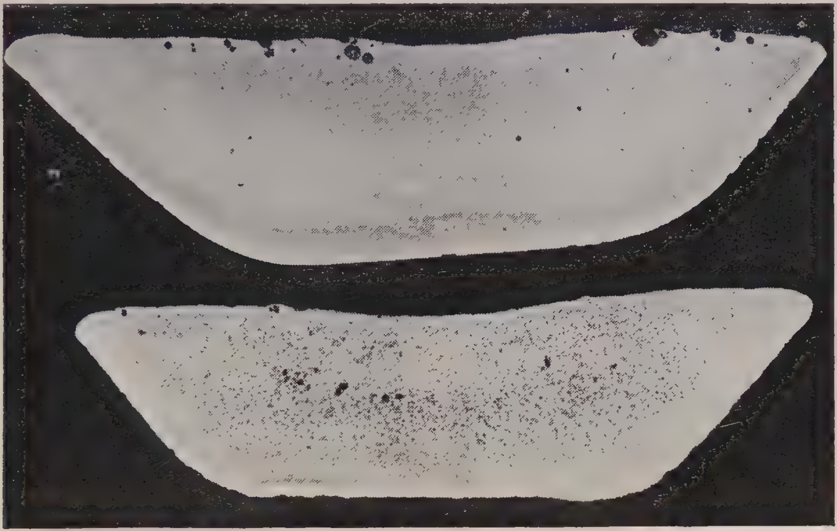

Fig. 27.—Photographs of Polished Sections of 10 per cent. Si Pig-iron, Cast in Uncoated Copper Mould (Above) and Cast in Coated Steel Mould (Below).

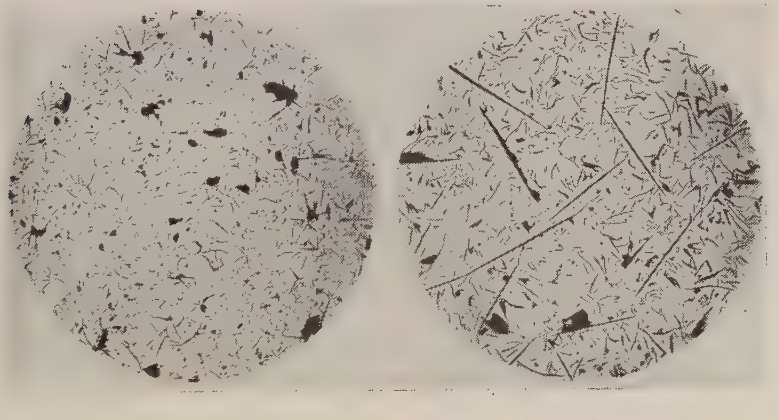

Fig. 28. Fig. 29.

Figs. 28 and 29.—10 per cent. Si Pig-iron, showing Sections of Chill Cast Iron, Air-Cooled, ¼ in. from Surface of Mould on Left and at Centre of Pig on Right, Both Unetched, × 100.

Inspection Control

The foundry industry has learned a great deal from the steel forging industry, both in the practical as well as the technical side of the business. The production of ArmaSteel requires much closer control and inspection than ordinarily given in the foundry industry, but due to the nature of the parts which this material is replacing, all available tests to satisfy the manufacturers that the part is sound and free from defects are made. Castings are dissected, polished and coarse etched in a hot acid bath to bring out any unsound areas, cracks, slag, or any other hidden defects. This is a daily routine on many castings. Fig. 30 shows this set-up. Magnaflux operations are performed on certain castings, which, due to their design, are prone to crack. Fig. 31 shows this operation on ArmaSteel motor vehicle pistons. Electric resisance testing for cracks is conducted on all camshafts. Fig. 32 shows this operation on ArmaSteel motor car camshafts.

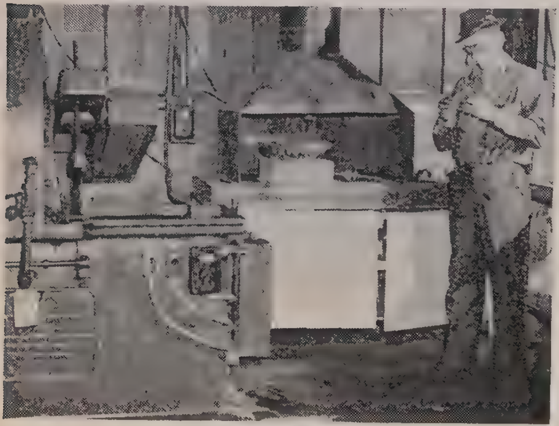

Fig. 30.—Cut-off Machine and Coarse Etching Acid Bath for ArmaSteel.

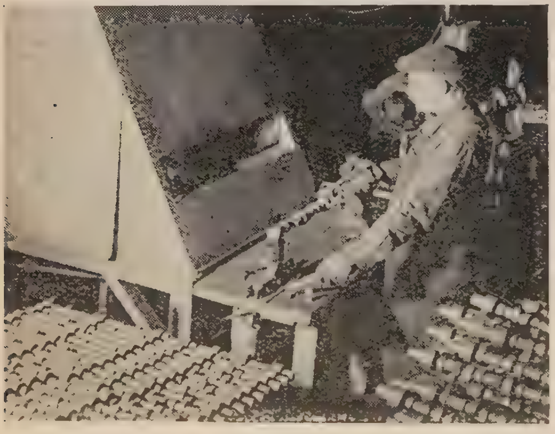

Fig. 32.—Electric Resistance Testing of Automotive ArmaSteel Camshafts.

Liquid pressure testing at 1,500 lbs. per sq. in. on lorry and railway Diesel pistons is carried out on every casting to guarantee soundness and absence of leakers. Many ArmaSteel parts are completely Brinelled, where the hardness limits are a controlling factor in the successful operation of the part.

Fig. 33 shows a set-up whereby every motor car rocker arm made is ground, Brinelled and inspected. These tests illustrate the extent to which inspection control is carried out to insure satisfactory performance.

Viewpoint of Graphitic Steel

The foundryman producing graphitic steel castings must take a long range view of his possibilities of continuing to produce this metal. A few years ago such promotion usually meant competition with ferrous and non-ferrous castings, forgings, weld fabricated structures, etc. To-day producers of those materials have plenty to do to get out production and less time to look into competitive markets.

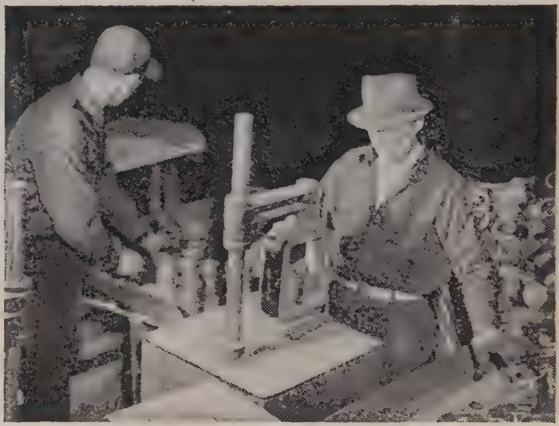

Fig. 31.—Magnaflux Testing on Automotive ArmaSteel Pistons.

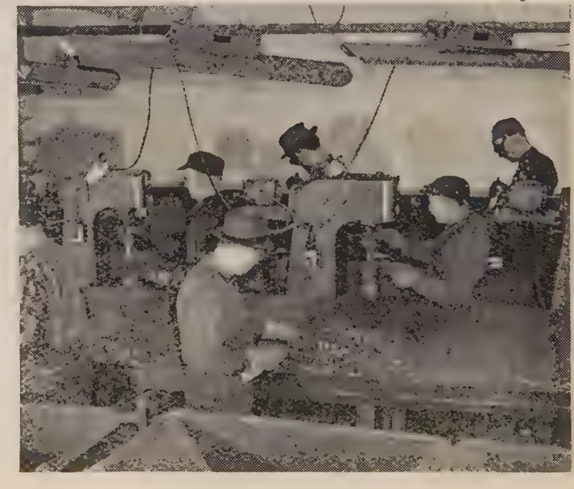

Fig. 33.—Brinell Testing of ArmaSteel Rocker Arms.

Piston Replacement

Prior to the curtailment and, finally, stoppage of motor-car production, ArmaSteel replaced aluminium for piston material. Aluminium alloys

CHART NO. 2.

1.—Name of Oven .... Location of Oven .... Superintendent ....
2.—Composition of Coals :
  Name ....
  Source ....
  Moisture ....
  Fixed Carbon ....
  Volatile Matter ....
  Ash ....
  Sulphur ....
3.—Ash Analysis :
  SiO_2 ....
  Fe_2O_3 ....
  Al_2O_3 ....
  Ca O ....
  Mg O ....
  Fusion Test ....
4.—Composition of Coal Mix :
  Per cent. ....
5.—Coal Sizing : .... per cent. through ⅛-in. sieve .... per cent. through ¼-in. .... per cent. through ½-in.
6.—Time coal exposed to weather ....
7.—Coke Ovens :
  1. Number running on our coke ....
  2. Size of ovens .... in. wide .... ft. high .... ft. long ....
  3. Weight of coal per oven .... tons dry
  4. Weight of coke obtained per oven .... tons dry.
8.—Coking Temperature .... deg. F.
9.—Time at Coking Temperature .... hrs.
10.—Are coke ovens running primarily for the making of coke or gas ....
11.—Is control of operation stressed ....
12.—Is the management progressive and open-minded ....
13.—Combustion Tests :
  1. Aver. rise in temperature ....
  2. Aver. time for 250 deg. temp. rise in .... min.
  3. Ignition temp. ....
14.—Coke Analysis :
  Fixed carbon ....
  Vol. Comb. matter ....
  Ash ....
  Sulphur ....
15.—Shatter Test : .... per cent. on 2 in. sq. screen.
16.—Structure of Coke :
  1. Cross fractured
  2. Soft
  3. Cell structure.
17.—Physical Properties :
  1. Apparent Specific Gravity
  2. True Specific Gravity
  3. Porosity
  4. Carburizing Action

machine more readily, have better heat conductivity and have less weight of moving parts. These offset the undesirable expansion characteristics of the metal, which are compensated for by design, and the higher cost of the metal per lb. To-day it appears that pistons will have to be made from some other material, and of all materials available, graphitic steel, without a doubt, offers the best replacement. At present motor-car and Diesel engines are successfully operating with pistons made from this material.

In an emergency many prejudices and preferences must be thrown overboard. Let it be assumed for the moment that the present emergency may bring about considerably more widespread use of graphitic steel as a replacement. It would be shortsightedness, indeed, to accept such changes as an Act of Providence and let it go at that. Unless foundrymen are alert to the possibilities, more ultimate harm than good may come from such replacements. Many applications have been brought to the attention of the foundryman, not because the manufacturer was willing to use another material, but because he found it necessary to do so in order to continue in operation. The old proverb, "Necessity is the mother of invention," has been found to hold true in the expanding use of ArmaSteel.

The gauge of any return to such parts as aluminium alloy pistons will be its engineering performance as against graphitic steel, availability of the metal and its ultimate cost. The current enormous expansion of the aluminium industry suggests that before long there will be so much aluminium available that it may go begging, and at a price per unit of volume that will give present replacements some close competition. The past year has seen a 25 per cent. reduction in the market price of ingot aluminium, and further reductions without a doubt are a possibility. This means that it will be necessary for the malleable foundryman to be just one jump ahead of his competitor and continue to produce a superior product which will keep him in the lead at all times.

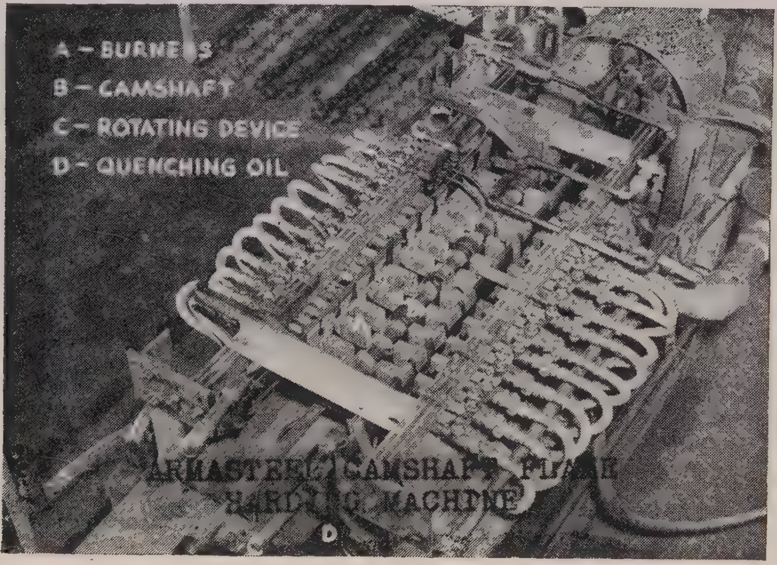

Fig. 34.—ArmaSteel Camshaft Flame-Hardening Machine.

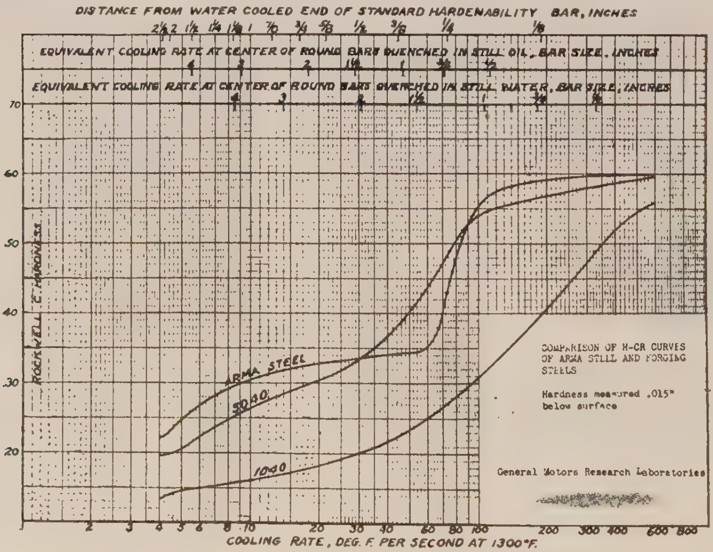

Fig. 35.—Comparison of Hardness/Cooling-Rate Curves of ArmaSteel and Forging Steels, with Hardness measured 0.015 in. below Surface.

Desirable Properties

ArmaSteel has many desirable properties which makes it outstanding in the ferrous field. In general, the *machinability* is from 10 to 30 per cent. better than steel forgings at the same Brinell hardness. The excellent *damping* characteristics are exhibited in the many parts, such as the camshaft. It has a *high yield ratio,* especially when a Brinell hardness of 200 or over is desired. Many installations have eliminated the bronze bushing, and the excellent *non-seizing properties* in metal to metal wear are recognised. This is illustrated in the elimination of the bronze bushing in the automotive rocker arm, operating on a hardened shaft. Crankshaft tests have proved the *high fatigue life* of ArmaSteel. One of its most valuable properties is that the metal responds readily to *localised* hardening, and a camshaft flame-hardening machine is shown in Fig. 34. This property is used in flame hardening and induction hardening of the cams on camshafts, shifter yokes and gears; also, the dipping of rocker arm pads in molten lead, followed by quenching. This surface hardness produces maximum wear resistance. High hardenability rating is a valuable property when this material is used to produce important gear parts. It has been found comparable to 5040-A steel, using the Jominy hardenability test-bar. Fig. 35 shows comparison of hardness cooling rate curves of ArmaSteel and forging steels, and Fig. 36 shows typical physical properties of ArmaSteel.

Hardness/Cooling-Rate Curves

Hardness-cooling rate curves show how the hardenability of ArmaSteel compares with other commonly used steels. By means of these curves, it is possible to predict what hardness can be obtained by heat-treatment of different sized sections. Knowledge of hardenability of different steels has made it possible to select the best steel for each part of the motor-car to permit obtaining the desired physical properties. This means of control has been a great aid in the more efficient use of metal, thereby increasing the performance of the car.

As the size of the part to be heat-treated increases, the speed at which it can be quenched decreases. As the speed of the quenching decreases, more alloy is required in the steel to obtain full hardening. Plain carbon steel will harden satisfactorily in light sections, but varying amounts of alloy in the steel are necessary for heavier sections, depending upon the size.

ArmaSteel has a hardenability similar to low alloy steels, and is suitable for full hardening up to $\frac{3}{4}$ in. dia. when oil quenched, or $1\frac{1}{2}$ in. dia. when water-quenched.

Machinability

One of the greatest advantages in favour of castings is the possibility of placing metal exactly where it will do the most good. This eliminates considerable machining. The reduction of machining operations severs one major bottleneck in many plants. Machine chips are the most costly things to produce, and the most useless. One great contribution to the Defence Programme which the casting industry can make is the time saved in the machining of castings as against forgings. Up to 50 per cent. in man-hours per part is being saved in many ArmaSteel castings replacing forgings. This is possible by producing castings to closer tolerances than forgings, thereby machining less excess metal.

A considerable saving in tool life is effected in the machining of the castings due to less metal removed and an easier machinable metal.

ArmaSteel castings show the following advantages:—

(1) Uniform structure for greater strength, shock and stress resistance.

(2) Metal distributed where it will do the most good, maximum strength, with minimum weight.

(3) Widest range of physical properties.

(4) Resistance to shock at sub-zero temperatures.

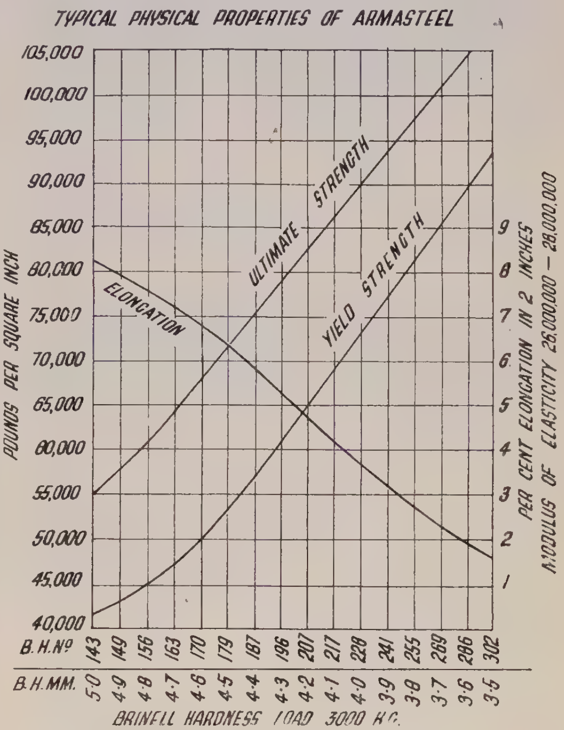

Fig. 36.—Typical Physical Properties of ArmaSteel shown Graphically.

(5) Responds to localised hardening, with high hardenability rating and maximum wear resistance.

(6) Good machining qualities, mirror finish, low finishing costs, better streamlined appearance.

(7) High rigidity, maximum deflection, accurate alignment, close tolerances and better fits.

(8) High fatigue resistance, maximum endurance and longer life. Ideal for critically stressed parts.

In the original Paper, the author included an illustrated appendix showing the types and properties of the castings made in the new material. This appendix commences overleaf.

Illustrated Supplement

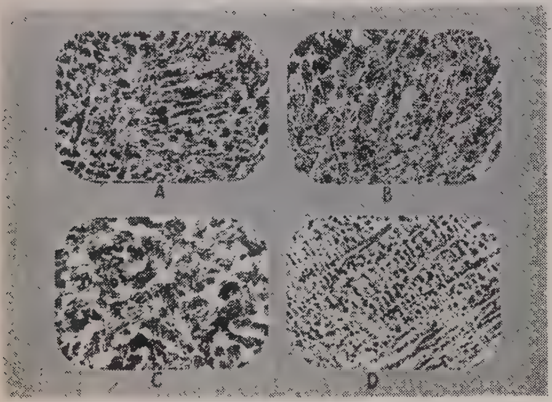

Fig. A.—Microstructures of White Cast Iron in Condition as Cast of Sections A, B and C from Brake Flange Hub Castings and Section D from Small Lever Casting. (× 100.)

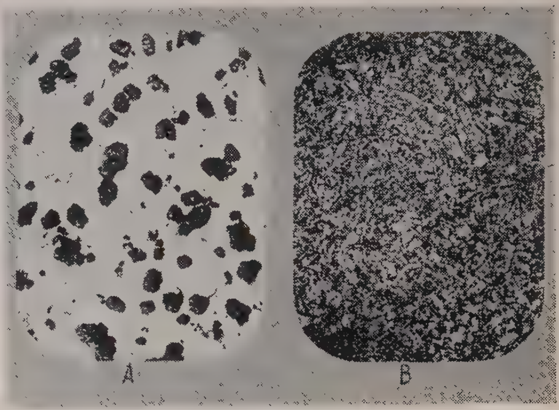

Fig. B.—Microstructures of Normal Malleable Iron (Left), and Grey Cast Iron (Right), Etched with 4 per cent. Nital. (× 100.)

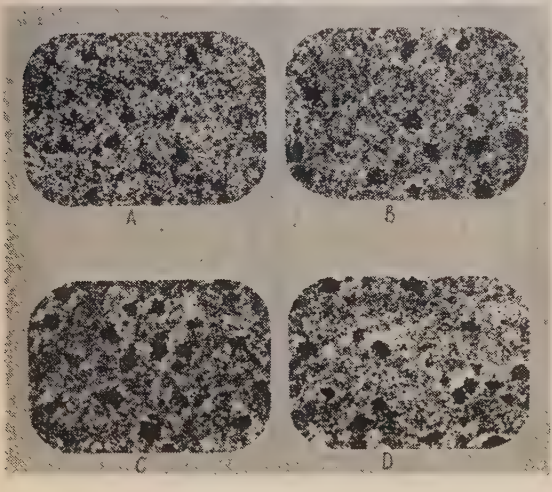

Fig. C.—Microstructures of Hard ArmaSteel, Etched with 4 per cent. Nital. (× 100.)

Top left: Air-quenched from 1,700 deg. F.; Brinell, 3.60 mm.

Bottom left: Air-quenched from 1,700 deg. F., drawn at 1,250 deg. F. for 4 hrs.; Brinell, 4.05 mm.

Top right: Air-quenched from 1,700 deg. F., drawn at 1,250 deg. F. for 2 hrs.; Brinell, 3.80 mm.

Bottom right: Air-quenched from 1,700 deg. F., drawn at 1,250 deg. F. for 5 hrs.; Brinell, 4.15 mm.

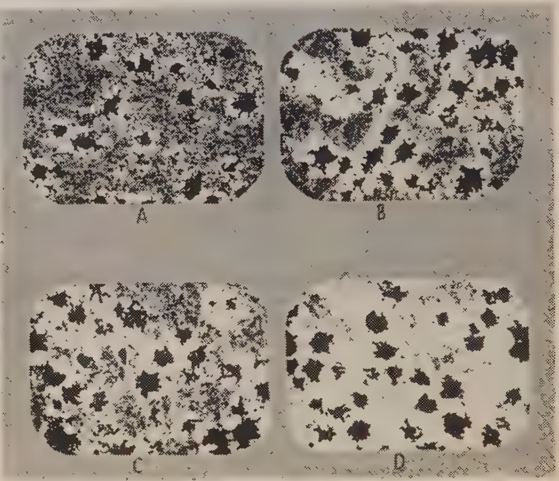

Fig. D.—Microstructures of Soft ArmaSteel, Etched with 4 per cent. Nital. (× 100.)

Top left: Air-quenched from 1,700 deg. F., drawn at 1,250 deg. F. for 6 hrs.; Brinell, 4.30 mm.

Bottom left: Air-quenched from 1,700 deg. F., drawn at 1,250 deg. F. for 10 hrs.; Brinell, 4.70 mm.

Top right: Air-quenched from 1,700 deg. F., drawn at 1,250 deg. F. for 8 hrs.; Brinell, 4.50 mm.

Bottom right: Air-quenched from 1,700 deg. F., drawn at 1,250 deg. F. for 12 hrs.; Brinell, 5.10 mm.

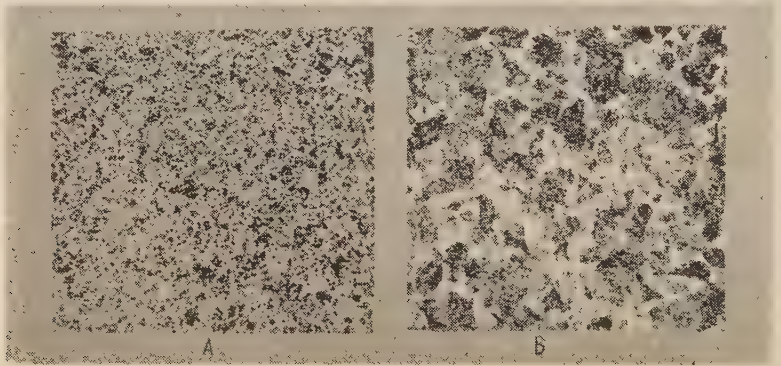

Fig. E.—Microstructures of 1050 Steel from Trunnion Block, × 100 on Left and × 500 on Right.

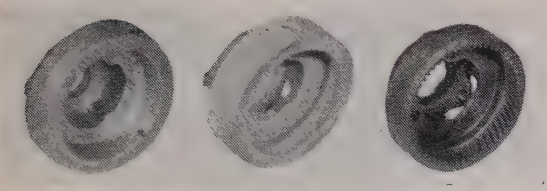

FIG. F.—HYDRAMATIC TRANSMISSION REAR UNIT OF INTERNAL GEAR AND CARRIER.

Left—forging, 6.45 lbs.; middle—rough casting, 5.2 lbs.; right—machined casting, 2.6 lbs.

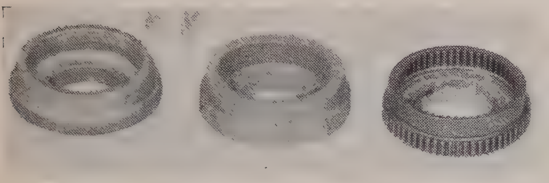

FIG. H.—REVERSE INTERNAL GEAR.

Left—forging, 8.4 lbs.; middle—rough casting, 7.5 lbs.; right—machined casting, 4.8 lbs.

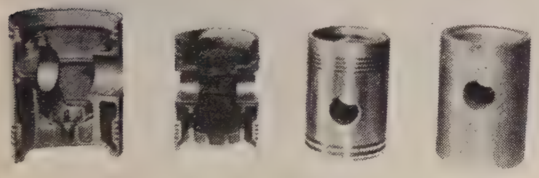

FIG. I.—4½- AND 6-IN. ARMASTEEL DIESEL PISTONS.

These pistons are used on Diesel engine truck motors produced to a Brinell hardness of 197 to 241.

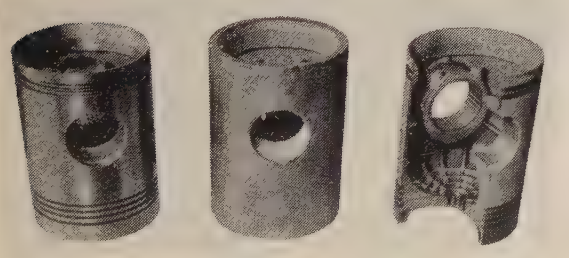

FIG. J.—ARMASTEEL 8½-IN. LOCOMOTIVE DIESEL PISTON.

These pistons are used on trans-continental streamline trains. The performance to date on these pistons has been remarkable. Many engines have reported upward to 1,000,000 miles without failure. Formerly aluminium and grey iron pistons failed at very low mileage.

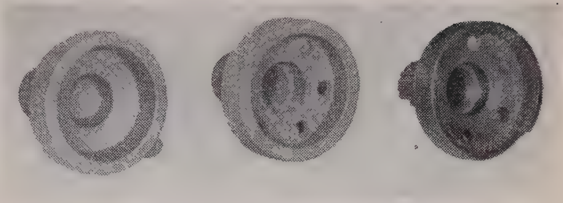

FIG. G.—FRONT UNIT DRUM.

Left—forging, 8.2 lbs.; middle—rough casting, 5.7 lbs.; right—machined casting, 3.3 lbs.

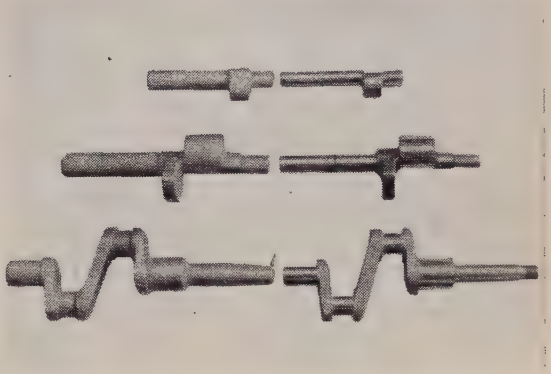

FIG. K.—ARMASTEEL ECCENTRIC AND THROW-TYPE CRANKSHAFTS.

The eccentric type was formerly 1112 or 1020 steel forging, carburised and hardened to a Rockwell "C" 60. The ArmaSteel shaft is produced to a Brinell range 170-207. This machines readily. After machining, it is heated to 1,550 deg. F., held 30 mins., oil quenched, drawn back to 700 deg. F., to a Rockwell "C" 40-45. The throw type were 1,045 steel forgings, heat treated to a Brinell of 207-255. ArmaSteel shafts are supplied to a Brinell of 197-241 and receive no further heat treatment.

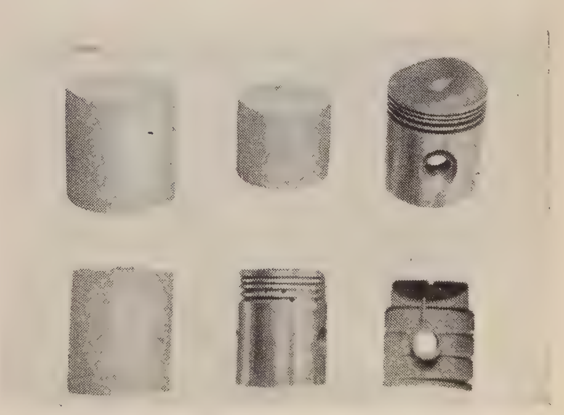

FIG. L.—ARMASTEEL AUTOMOBILE PISTONS.

ArmaSteel pistons formerly produced from aluminium are giving satisfactory service. Due to its greater strength, ArmaSteel can be machined to a thinner wall thickness and correspondingly lighter weight than grey iron. In general, a grey iron piston is 80 per cent. heavier than aluminium; whereas, ArmaSteel is 45-50 per cent. heavier. ArmaSteel pistons can be machined to equal the weight of aluminium, but this requires considerable machining.

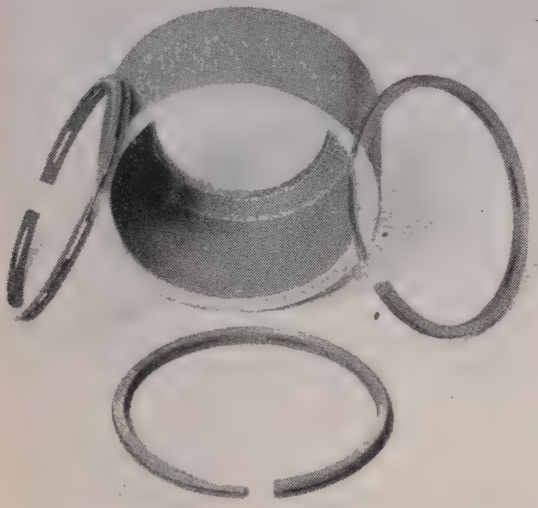

Fig. O.—ArmaSteel Motor-Car Piston Ring Pot with Machined Rings.

Six piston rings are cut from the 2 in. long pot. The internal flange is used for chucking. The rings are machined and ground after slicing. Two advantages are outstanding on ArmaSteel piston rings. One is that the bore finish does not have to be honed as smooth, since the action of ArmaSteel smooths up the bore and has what is called a healing action; and the other is the ability to conform to the shape of the bore—the ring comes in quickly, that is, it seats promptly. ArmaSteel rings are referred to as "self-seating." The material is supplied to the piston ring manufacturer at 228-255 Brinell.

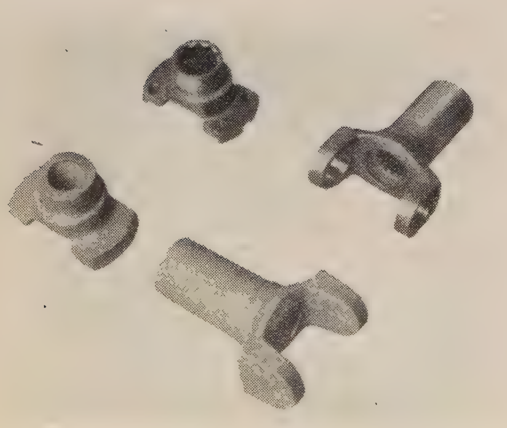

Fig. P.—ArmaSteel Rear Propeller Shaft Flange (Left) and Front Universal Joint Yoke (Right).

These parts formerly 1145 steel forgings. Quenched in oil and drawn to Brinell range of 255-302. Considerable trouble was experienced in broaching the splines. The ArmaSteel parts are produced to a Brinell hardness of 207-255. Broaching operation has caused no trouble. This is a highly stressed part and has shown up very satisfactory.

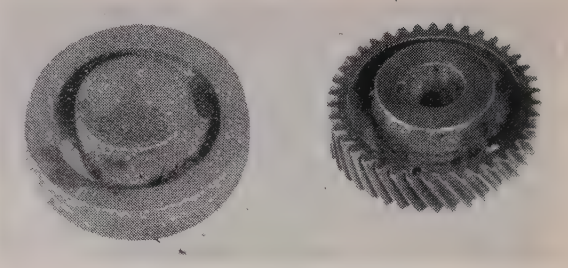

Fig. N.—ArmaSteel Washing Machine Gear.

This gear was produced from different materials which did not give satisfactory service. ArmaSteel is supplied at 300 Brinell, at which hardness the gear teeth are cut, and no further heat treatment is given. This part is an outstanding example of machinability of ArmaSteel at high hardness, and is turning in a satisfactory performance record.

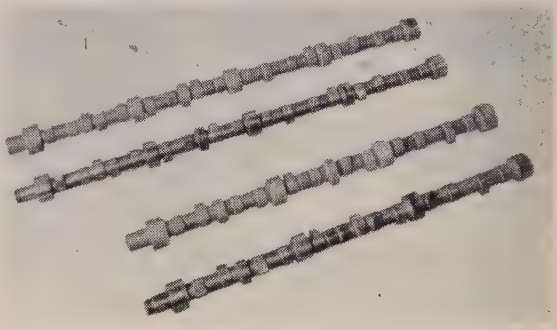

Fig. Q.—Motor-Car Camshafts.

Many advantages can be credited to ArmaSteel as a camshaft material, in addition to savings of pattern expense versus cost of forging dies. These advantages are: (1) Elimination of rough machining of cams; (2) only one centreing operation; (3) less metal removed in machining; (4) elimination of carburising; (5) better tool life; (6) easier straightening; (7) better production on existing equipment; (8) less finished weight; (9) added quietness to motor due to damping property; (10) less handling and transportation due to straight line production. Camshafts must resist wear and be sufficiently rigid to give a satisfactory low noise level. The strength of camshafts is secondary in consideration, because if the design and material used is sufficiently rigid it is inherently strong enough. Most of the automobile camshafts are 1020 steel carburised and hardened. ArmaSteel shafts are produced to Brinell range of 197-241, and cams and gears either flame-hardened or induction-hardened.

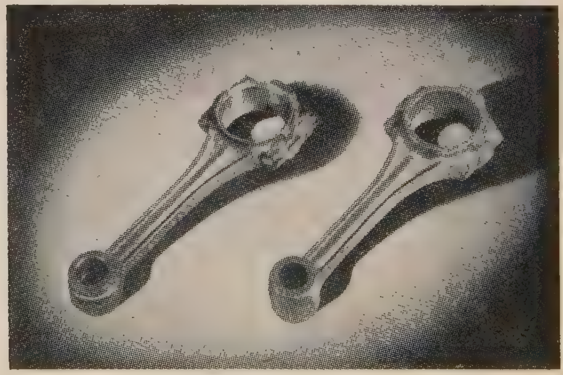

Fig. R.—Motor-Car and Refrigerator Connecting Rods.

1035 steel forging was formerly used. For refrigerator rods ArmaSteel at 163-207 Brinell is being used. For automotive rods ArmaSteel at 197-241 Brinell has proved very satisfactory.

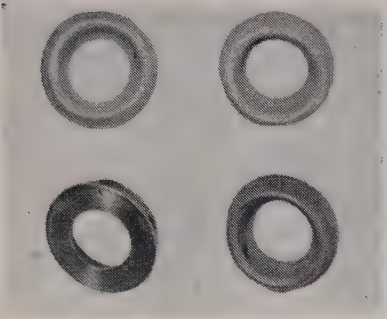

Fig. M.—ArmaSteel Motor-Car Clutch, Throw-Out Collar.

This part was formerly a 1045 steel forging, hardened to Rockwell "C" 55 minimum. The present ArmaSteel casting is supplied at 197-241 Brinell, coined on the round surface, three holes drilled, hardened to 42-46 Rockwell "C," rough and finish ground on the flat side.

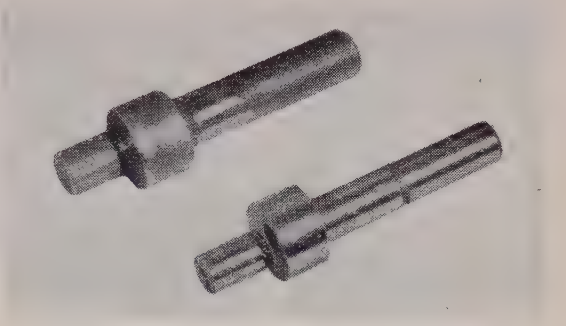

Fig. T.—Refrigerator Crankshaft.

This is called the eccentric type. It was formerly either 1112 or 1020 steel forging, carburised and hardened to a Rockwell "C" 60. The ArmaSteel shaft is produced to a Brinell range 170-207. This machines readily. After machining, it is heated to 1,550 deg. F., held 30 mins., oil quenched, drawn back to 700 deg. F. to Rockwell "C" 40-45.

Fig. S.—Motor-Car Valve Rocker Arms.

Formerly produced from 1020 steel, carburised and hardened. Also from 1035 steel and hardened. The pad end was immersed in lead pot and quenched in water. One customer prefers a soft ArmaSteel 143-179 Brinell and allows a little longer time for heating in the lead bath. The other customer specifies 179-207 Brinell and also quenches in oil from a lead bath, immersing the pad end only. Minimum 50 Rockwell "C" on pad is specified. The excellent non-seizing properties of ArmaSteel in metal to metal has made it possible to eliminate the bronze bushing formerly used on the steel forging.

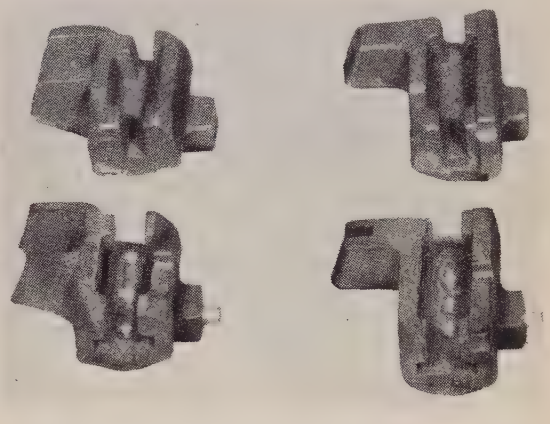

Fig. U.—Shifter Forks.

These parts are in an automotive transmission. They were formerly 1035 steel forgings, gas carburised and hardened to Rockwell "C" 60. The ArmaSteel parts are produced to a Brinell range of 207-255. At this hardness, machining has been found to be satisfactory. The inner surface and one notch on each fork are flame-hardened with an oxygen-acetylene burner by heating for 17 secs. and quenching in water. The hardening machine is automatic, one man hardening more than 6,500 forks from a machine in eight hours.

PRESENTATION OF PAPER

In the absence of the author, the Paper was presented to the meeting by Mr. A. E. Peace, Convener, Malleable Cast Iron Sub-Committee of the Institute's Technical Committee.

Mr. A. E. Peace, introducing the Paper, said he was pleased to be privileged to present this Paper on behalf of Mr. Joseph, first because it was an American Exchange Paper, secondly because Carl F. Joseph was a distinguished malleable metallurgist and was associated with what he believed was the largest malleable iron foundry in the world, and thirdly, because it was the first Paper upon the subject of pearlitic malleable cast iron to be presented to the Institute. In the early part of the Paper Mr. Joseph drew attention to the need for increased technical control in the malleable industry, and pointed out that wartime conditions had stimulated consideration and investigation of materials to replace many steel and non-ferrous parts. The paragraph headed "Castings and Forgings" was of considerable importance, and was elaborated by illustrations and data which he would refer to later, although they were not in the printed Paper.

Derivation of Word "ArmaSteel"

Many would question the use of the word "steel" in describing this product, and Mr. Joseph's mention of a reference to it as graphitic steel. The trade name used had been built up from the Ar critical point and part of the word malleable, the word steel being used in reference to the matrix of the material which resembled spheroidised steel. The technical world, of course, would describe this material as a pearlitic malleable cast iron, and he believed he was right in saying that they drew a dividing line between steels and cast irons by the presence or otherwise of eutectic carbon, which gave a limit for steel at a maximum of around 1.70 per cent. The metal as cast was a white cast iron of composition similar to that of blackheart malleable. The heat-treatment was carried out in two stages, annealing over a period of around 15 hrs. at 950 deg. C., completing first stage graphitisation, the castings being cooled to about 870 deg. C., and then air- or oil-quenched. Second stage graphitisation was carried out by heat treatment at 675 deg. C. for a period of from 4 to 12 hrs., depending upon the physical requirements. The combined carbon remaining was such as to give properties comparing favourably with those of forgings in the 1,035-1,050 range. These numbers, and others used subsequently, referred to classification of steels under a numerical system designed by the American Society of Automotive Engineers. The first figure (1) signified plain carbon steel and the latter two figures indicated the carbon content, *e.g.*, 1,035 was a 0.35 per cent. carbon steel. Later numbers, 1,112 and 1,145, referred to what would be called free cutting steels of 0.12 and 0.45 per cent. carbon content. The steel later referred to as 5,040, was a carbon chrome steel.

The range of tensile properties obtainable in ArmaSteel was shown in Fig. 36, together with the Brinell hardness values. It might be of assistance if he gave some conversion of the lbs. per sq. in. to tons per sq. in., *e.g.*, 60,000 lbs./sq. in., was equivalent to 27 tons, and 100,000 lbs./sq. in. was equivalent to 45 tons. The yield ratios in this material at the bottom of the curves were approximately 74 per cent., increasing to 85 per cent. at the top of the curve.

Mr. Joseph considered that the raw materials going into the charge had more effect upon properties than the melting equipment used, and enlarged upon this in respect of pig-iron and cupola coke. His melting process was duplexing with cupola and electric furnace, and therefore a charge comprising high silicon pig-iron, steel scrap and re-melt was used. Chart No. 1 gave a schedule of the data collected at the blast furnace when the pig-iron was made, and it would be surprising to many to see the extent to which Mr. Joseph went in looking after his pig-iron supplies. The Paper stated that microscopical examination of the pig-iron was carried out as a routine test, and it then referred to annealing difficulty which has been encountered with metal made from pig-iron in which appreciable amounts of steadite were present. Mr. Joseph proceeded further to show the effect of graphite size in the pig-iron upon the size of the free carbon nodules produced in the finished material. Although Mr. Joseph only referred specifically to the effects of steadite and graphite size, he gave a hint that these were not the only features affecting the quality of the material.

Regarding control of the product, it would be seen that tests and inspection were carried out to a rather unusual degree for foundry work. Special tests had been devised for certain castings, and use was made of magnetic and electrical resistance testing in addition to pickling, hydraulic and hardness testing. Many of these types of inspection were carried out on castings to 100 per cent.

The Appendix

It was emphasised that the replacement of parts by new materials, which under present circumstances might be the outcome of necessity, could only be permanent upon the basis of engineering performance, availability of material and ultimate cost. In the Appendix were illustrated diesel engine pistons made in this material for automobile work and for trans-continental trains, and reported performance on the latter up to 1,000,000 miles without failure. In assessing advantages of castings in this metal as compared with steel forgings, photographs and data were given, and Mr. Peace said he would just quote that in automobile transmission gears, and in an internal gear drum used presumably on front wheel drive vehicles, reductions in rough weight of castings against forgings are shown of 20, 30 and 11 per cent., and these reductions had resulted in 32, 51 and 25 per cent. less metal to be removed in machining. Numerous examples were given of crankshafts, camshafts, universal joint yokes, propeller shaft flanges, rocker arms and light parts which have replaced medium carbon steel forgings and case-hardening steels. Photo-micrographs were shown giving the comparison between ArmaSteel and other metals, and the series of photo-micrographs for ArmaSteel covered material with a range of 140 to 300 Brinell, and tensile strengths of 25 to 45 tons per sq. in.

Attention was drawn to various properties such as machinability, damping, high yield ratio, non-seizing properties, fatigue strength and response to localised hardening. In connection with the last, it was shown that ArmaSteel has a high hardenability rating, and compared favourably with the 0.4 per cent. carbon chrome steel. Data upon the response to hardening were given in Fig. 35, and the curves extended over a range of 200 Brinell up to 575.

In conclusion, Mr. Joseph gave a list of advantages claimed for ArmaSteel castings, and drew attention thereby to the fact that tensile strength, which was so popularly used as the evaluation of a material, was frequently of less importance than many other properties which were not so commonly referred to. Mr. Peace particularly mentioned point (2), which applied generally to castings in all metals. By comparison with forgings, it was a paramount advantage that in a casting it was possible to obtain the metal distributed where it would do the most good, giving maximum strength with minimum weight. This entailed great attention to design, and great endeavours on the part of the foundrymen to produce more accurately to dimensions.

DISCUSSION

Mr. G. R. Webster asked if it were possible to have further details of the furnace equipment used in connection with the manufacture of ArmaSteel.

Mr. Peace said that unfortunately this Paper had only recently arrived in this country and it had been impossible for him to correspond with Mr. Joseph on matters upon which further information might be required. However, a note would be made of the request of Mr. Webster and Mr. Joseph would be asked to elaborate in his written reply to the discussion.

The **Chairman** (Mr. D. Sharp) said the furnaces were almost a duplicate of those used by the Ford Company at Dagenham.

Compositional Ranges

Mr. T. R. Twigger commented on the use of the term "white cast iron" in the Paper and expressed the hope that when more leisurely days came again the Technical Committee would have on its agenda once more the question of nomenclature, although not as an item which in the past had always been carried forward to the next meeting.

Continuing, he said the Paper illustrated a very interesting material and one point of considerable importance was whether there was any advantage in doing the oil hardening and tempering during the heat-treatment cycle. He had in mind that where a high degree of hardness finish was required it might be more profitable to fully-anneal and then re-harden. Again, more information was wanted with regard to the possible range of analysis. One definite composition only was mentioned and it was easy to imagine that the silicon content would have a very potent effect on the hardness and test figures. If Mr. Peace could obtain more information with regard to this, it would be valuable. He would also be very interested to have particulars concerning the effect of the alloy additions, particularly molybdenum, because he believed that in this way extremely useful properties could be given to the material.

Finally, with regard to the possible applications of this material, it seemed more likely that it would replace steel, particularly forged steel, and he did not think the case for the replacement of aluminium was particularly good, even with the present short supply.

Mr. Peace said he was very pleased to have had this contribution to the discussion as it had opened up some aspects which perhaps he had not dealt with adequately in presenting the Paper. In the first place, there might be some doubt as to what was pearlitic malleable and why it was so called. The answer was that in blackheart malleable it was only possible to produce a product which finally had a structure of ferrite and free carbon in nodular form. That had been the accepted type of blackheart malleable for years. Pearlitic malleable referred to a somewhat similar material but instead of a ferrite matrix there was a matrix which was composed of pearlite or any other of the transition stages from martensite downwards.

With regard to hardening as a separate operation, it should be mentioned that this was only one type of pearlitic malleable that was produced. Actually there were well over a dozen different types. Pearlitic malleable was produced by different people in different ways and it was just that they had their own fancy ideas how to do it. He himself had been producing pearlitic malleable for 10 years and in his case he carried out what was the normal blackheart annealing treatment and re-heated the material before hardening, which was what Mr. Twigger had suggested.

Variations in Composition

As to variation in composition, the important thing to remember was that a metal was being cast which must not show any primary graphite in the "as cast" state. Therefore, it was necessary that the carbon, silicon, manganese and sulphur ratios must be such as would not favour primary graphitisation. His own work was as near the borderline as possible, which necessitated that there should be very little latitude in the composition. As regards carbon content, however, one would not work to a greater variation than, perhaps, a total range of 0.40 per cent., but in silicon content much closer than that. In Mr. Joseph's case he believed the silicon content was between 1.3 and 1.4. In manganese there might be a range of 0.05 per cent., and perhaps sulphur would be 0.02 per cent.

Concerning alloy additions, these fell mainly into two classes, *viz.*, those alloys which favoured graphitisation, and those which stabilised the carbide. Therefore, in using alloys they were used because either of these things were wanted or they were used to counteract these effects. Molybdenum, in comparison with chromium, was a mild carbide stabiliser and it would be necessary to increase the silicon content somewhat. Actually in these pearlitic malleables, alloys were not usually used because the improvement in properties generally was not considerable. They always had to be dealt with very carefully.

The meeting expressed its thanks to the author, and also to Mr. Peace for presenting the Paper. Mr. Peace, acknowledging, asked for written contributions to the discussion and promised that Mr. Joseph would reply to all the comments made on the Paper.

Paper No. 752

The Substituting of High-Duty Grey Iron for Steel Castings

By J. BLAKISTON, A.I.Mech.E. (Member)

When asked to prepare this Paper, the writer was faced with the necessity of following a galaxy of Papers on the development of high-duty grey iron* presented during the last decade by the cream of the metallurgical and foundry industries. It is therefore proposed that, in this particular instance, stress is laid on what advantages the engineers have taken of these, what may be called revolutionary developments in the cast-iron industry. The first portion of the Paper will be devoted to concrete examples of high-duty grey iron displacing cast steel. " It will be noted that the term cast iron, in view of the developments which have taken place, is now an obsolete term."

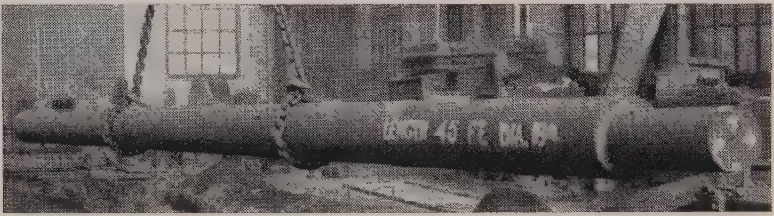
FIG. 1.—BORING BAR.

The examples cited are not experiments, but proved cases kindly supplied by engineering firms of repute whose names are household words. This increase in the use of high-duty grey iron has been progressively accelerated by war conditions and presents extending potentialities for post-war developments at the same expansion rate as at present. The second portion of the Paper will describe how the small ironfounder, an engineer, who in many cases has yet been untouched by these developments, can proceed to manufacture some of the grades of this iron. This section has been introduced because sometimes the industry is inclined to forget that the larger percentage of the

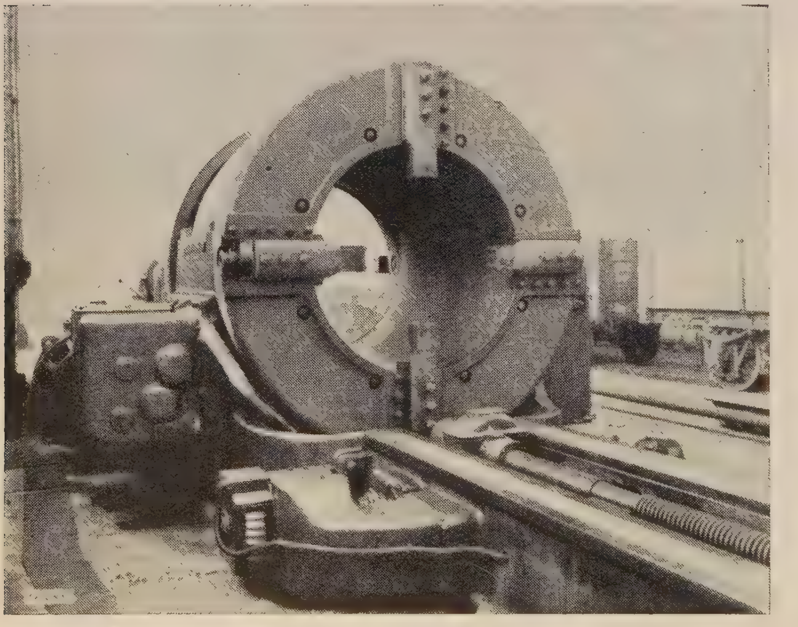
FIG. 2.—BORING LATHE HEAD.

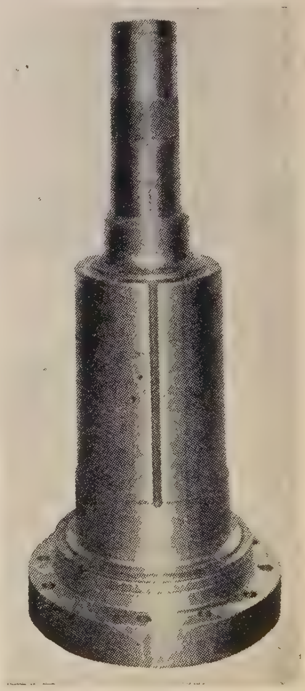
FIG. 3.—FINISHED MEEHANITE SPINDLE.

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* See list of references at end of Paper.

2,000 ironfoundries in this country have no technical control of their product, and although probably averaging less than 20 tons output per week individually, collectively produce the major proportion of grey-iron castings consumed in this country. The third and last portion of this Paper will discuss the latest trends and probable future developments in the high-duty grey-iron field.

Cast-Iron Crankshafts

High-speed Diesel and petrol engines are fitted with grey-iron crankshafts as a matter of course. Before Ford fitted his mis-named cast-iron (actually hyper-eutectoid cast-steel) crankshafts to his standard car models, many American manufacturers had been using high-duty grey-iron crankshafts for refrigerators and such like machinery, but kept the matter secret, as they were afraid of public prejudice against cast iron. While the foundry has brought the potentialities of modern irons to the fore, it must be realised that engineering advancement has also extended considerably in several ways, such as increased power and stability of modern machine tools, enabling heavier cuts to be taken on tougher material economically; improvement in cutting-tool properties by the introduction of tungsten carbide, which renders castings machinable more or less independent of hardness;

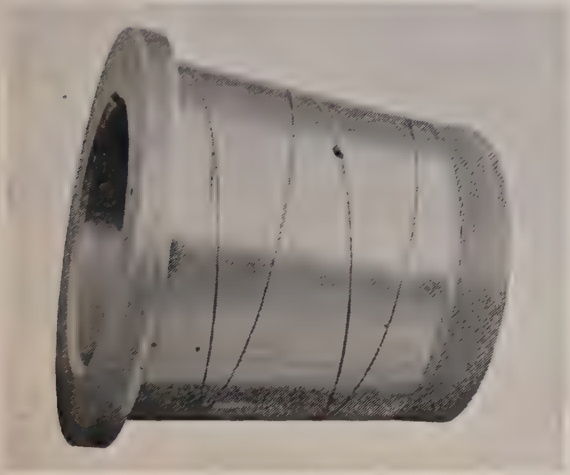

FIG. 4.—SPINDLE NECK.

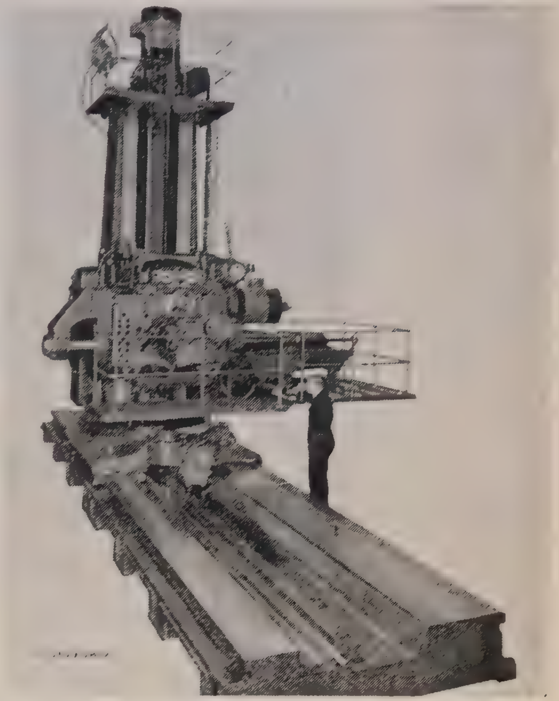

FIG. 5.—HORIZONTAL BORER.

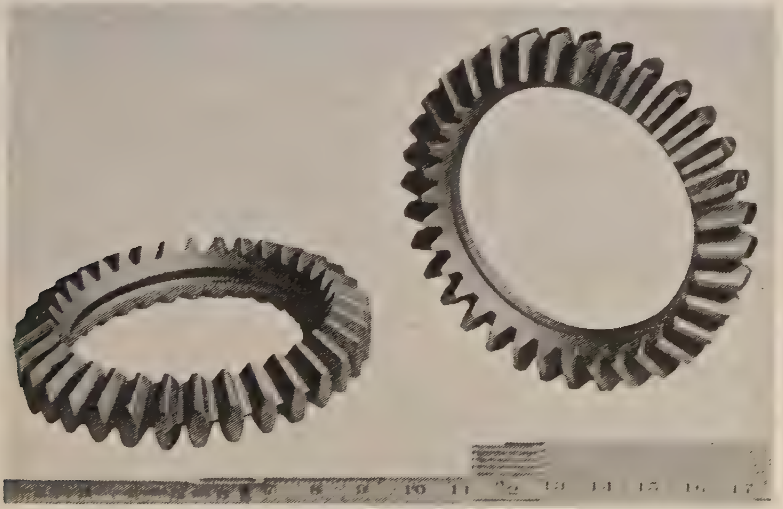

FIG. 6.—GEARS FOR FEED SYSTEM CONTROL GEAR.
V NOTCH MACHINED AND FLAME HARDENED.

and improvement in engineering finish and limits, particularly by precision grinding, which reduces breakages caused by misalignments and reduces hammer action by maintenance of correct bearing clearances.

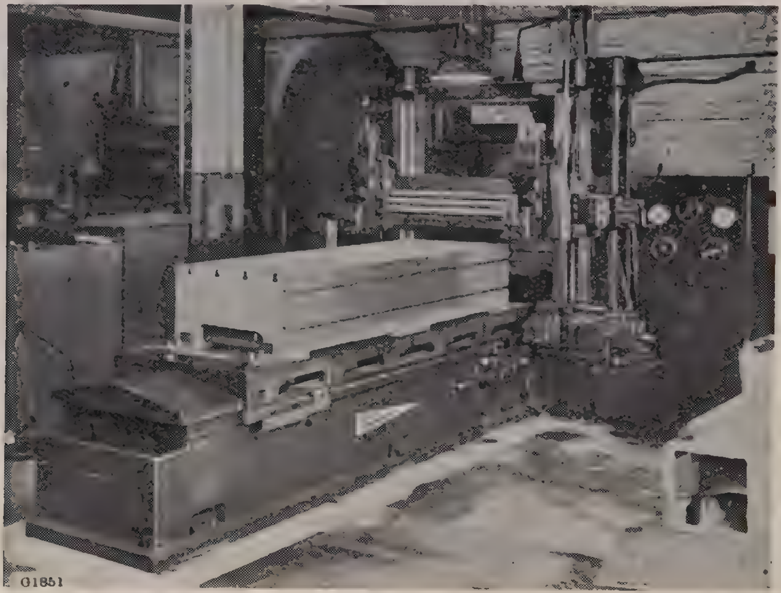

Fig. 7.—Planing Machine.

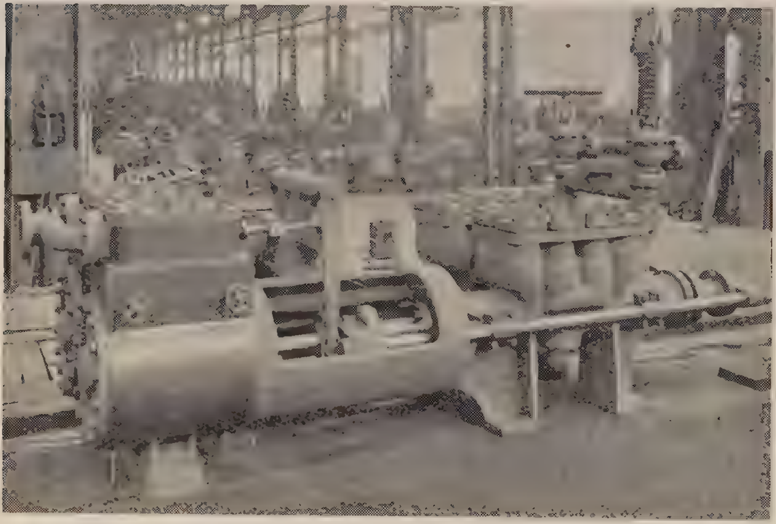

Fig. 8.—Oil Pump.

Spindles in High-Duty Irons

Figs. 1 to 4 show typical examples of the use of high-duty cast iron for various types of spindles. The first shows a 45-ft. by 1-ft. 6-in. solid boring bar,[2] replacing a costly steel forging. Fig. 2 shows a large boring lathe head, the hollow spindle being constructed of 19 to 20 tons tensile iron and weighing approximately 6 tons in the rough state.

Fig. 3 depicts a milling machine spindle. It has been found in practice that, by the use of high-duty grey-iron spindles, it is possible to operate lathes, milling machines, etc., at a much higher speed utilising the remarkable properties of tungsten-carbide cutting tools to their fullest advantage on account of the vibration absorption properties of grey iron.[3]

Fig. 4 shows a horizontal boring machine main spindle neck bearing made from typical grey iron. This revolves in a bronze bush, and the bearing qualities of the combinations are excellent. These bearings are fitted into machines similar to that shown in Fig. 5. It will be seen from the first four illustrations that, apart from its tensile properties, this iron has excellent machinability, taking a fine finish even when extended to fine screw cutting on heavy sections.

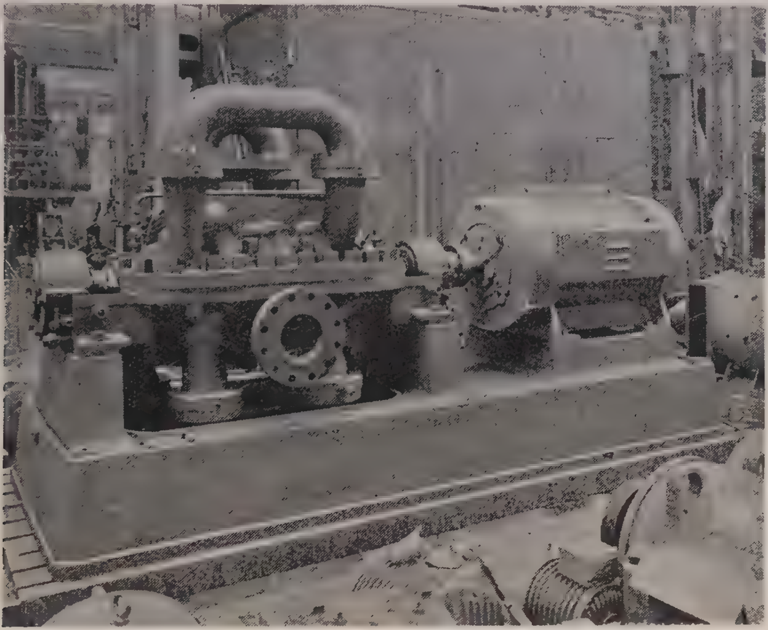

Fig. 9.—Feed Pump.

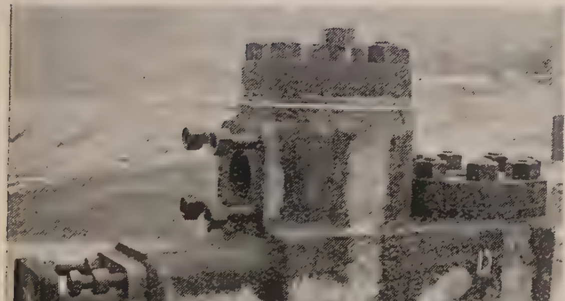

Fig. 10.—Hydraulic Pump Body. Grade A Meehanite, 24.7 tons Tensile; 4,500 lbs. and 0.302 in. def. on 1.2-in. dia. Transverse. Weight 22 cwts. Replacing Body Cut from Steel Billet.

The next three illustrations show the use of high-duty iron in one of its pioneer and most popular forms.[3] Fig. 5 shows a horizontal boring machine, the main traverse rack and column rotating rack of which were formerly made in 0.4 per cent. carbon green steel replaced by high-tensile grey iron having a tensile strength of 25 tons. Fig. 6 shows fuel-system flame-hardened machine gears; all high-duty irons lend themselves very readily for nearly all heat-treatment processes.[4] Fig. 7 shows a modern heavy high-duty speed planing machine. The main table rack, which is not shown in the picture, was formerly made in steel, also the tool clapper boxes. Modern grey irons readily meet the arduous services required and take the shock of high-speed reversals without fear of failure.

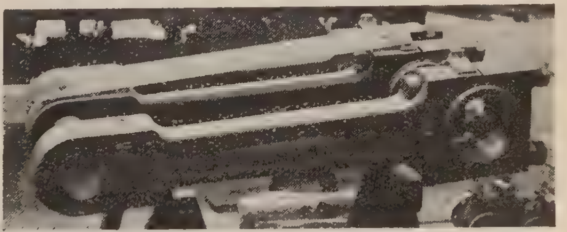

Fig. 11.—Pump Connecting Rod. Grade C Meehanite, 19.1 tons Tensile; 4,000 lbs. and 0.301 in. def. on 1.2-in. dia. Transverse. Weight 3½ cwts. These Connecting Rods have been Redesigned to give the Best Possible Service in Relation to the Former Steel Forgings used.

In the case of the replacement of steel gearing, the improvements in gear-cutting methods and the advance in engineering technique previously referred to have helped to no mean extent, and the quietness in operation of high-duty grey-iron gears has become an accepted fact. Figs. 8 to 12 give examples of developments which have taken place in the pumping field; Fig. 8 shows a unit for pumping oil at 800 lbs. per sq. in. pressure, originally made from cast steel, but now operating satisfactorily in modern grey iron. Fig. 9 shows a centrifugal boiler feed pump working at 600 lbs. per sq. in. pressure, and the caption by the makers is that the increase in confidence between designers in high-duty irons has been justified by the results obtained.

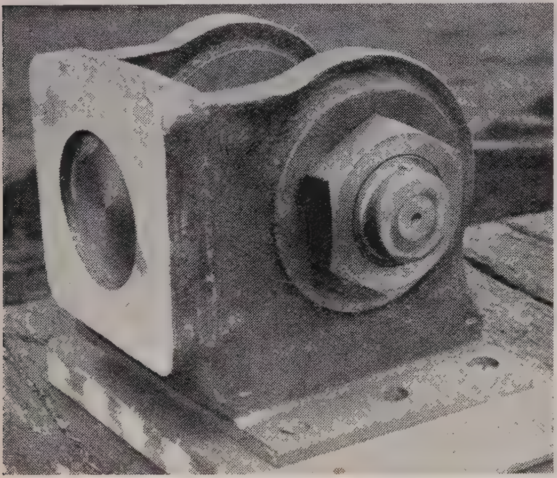

FIG. 12.—PUMP CROSSHEAD. GRADE A MEEHANITE, 25.6 TONS TENSILE; 4,300 LBS. AND 0.258 IN. DEF. ON 1.2-IN. DIA. TRANSVERSE. WEIGHT 1½ CWTS. REPLACING CAST STEEL.

Fig. 10 shows an outstanding case where a hydraulic pumping body, formerly cut from billet, has been made from high-duty iron with a tensile strength of 25 tons per sq. in. The connecting rods and cross-head for this pump are another two striking adaptions and are shown in Figs. 11 and 12. Fig. 13 shows a 250-ton extrusion press body, which was formerly made in steel and is now made in high-duty iron with 22 tons per sq. in. tensile. The weight of this casting is 3 tons 12 cwts.; a similar casting made in the early types of cast iron would have indeed been a massive affair.

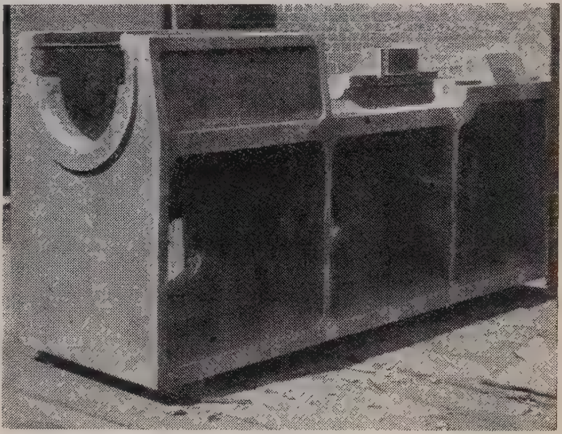

FIG. 13.—250-TON EXTRUSION PRESS BODY. GRADE A MEEHANITE, 22 TONS TENSILE. WEIGHT 72 CWTS.

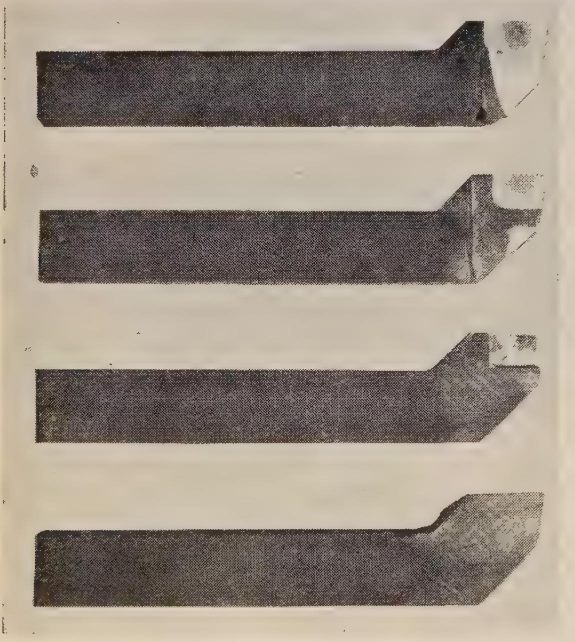

FIG. 14.—TYPICAL MEEHANITE TOOL SHANKS FOR SINTERED CARBIDE TOOLS.

Earlier illustrations show how modern iron spindles enabled machine tools to obtain the best result from tungsten-carbide cutting tools. This development has logically been taken a step further, and Fig. 14 shows a series of tool shanks. It has been found that it is practicable to make any tool shank of greater section than 1 in. square from high-duty grey iron with beneficial results, but it is necessary for the tips to be brazed on by external heat. The attachment of the tips by electrical-resistance heating methods up to the present is not satisfactory for this new development in the use of grey iron. The illustrations which have been dealt with up to now are only a few taken at random from an enormous field of successful applications, but the range is eloquent in its descriptiveness.

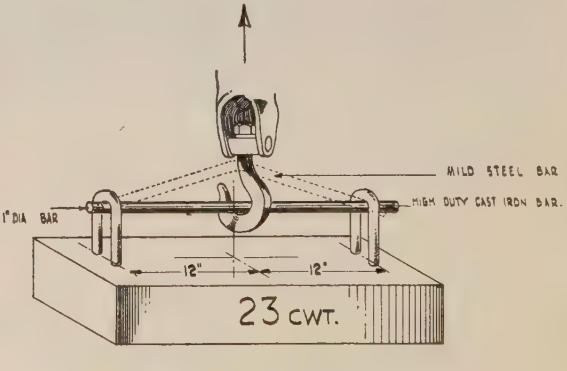

FIG. 15.—TEST WEIGHT.

Convincing the Engineer

The small-scale ironfounder when contemplating the manufacture of these newer irons has first of all to convince his customer or his associates in the engineering shops as to the potentialities of his products. With the practical man on the bench and even in the case of certain members of the administration, tensile tests and figures cut no ice, and the following series of tests, which are very simple, have gone a long way to influence certain sections of the engineering community as to the possibilities of these new irons. As the small-scale ironfounder cannot be expected to own a complicated testing machine, Fig. 15 shows a simple device by means of which not only can he determine whether a satisfactory iron has been obtained from his furnace, but will impress personnel with his results.

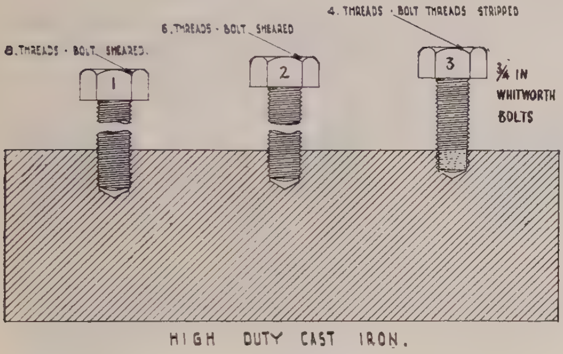
4. THREADS · BOLT THREADS STRIPPED
6. THREADS · BOLT SHEARED
8. THREADS · BOLT SHEARED.
1
2
3
¾ IN WHITWORTH BOLTS
HIGH DUTY CAST IRON.

FIG. 16.—SHEAR BOLTS.

The apparatus consists of a block of cast iron weighing 23 cwts. with two loops cast in 24 in. apart. If a 1-in. dia. cast-iron test bar is placed between these loops, and it has a tensile strength of 23 tons upwards, it should be possible to lift this block from the centre by means of a crane hook. Should a 1-in. mild steel bar be substituted for the cast iron bar it will be found that the block cannot be lifted, as the yield point of the mild steel is considerably below that of the weight of the block.

Test 2 is set up as in Fig. 16. A block of high-duty iron has three blind holes drilled and tapped ¾ Whitworth thread, the first hole being eight threads deep, the second hole being six threads deep, and the third hole being four threads deep.

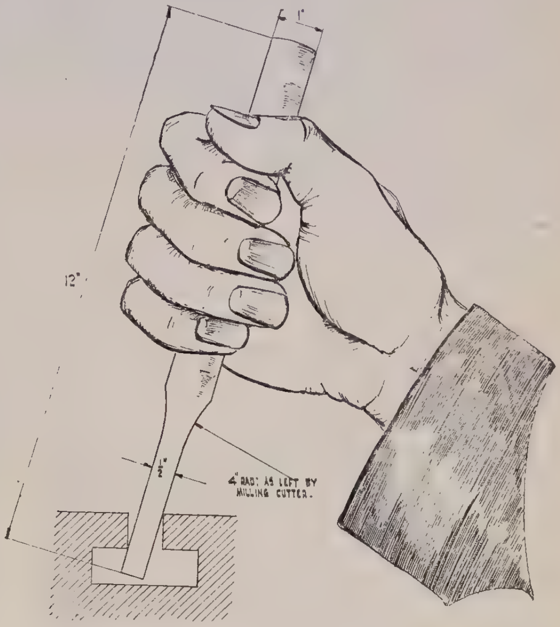

FIG. 17.—SHOCK TEST.

Even when using high-tensile steel tap bolts, it will be found that when the bolts are screwed hard against the bottom of the hole and full leverage is exerted by means of a long spanner, the bolts will shear off in the case of No. 1 and No. 2 bolts before the thread strips, and that in the third case it will be the steel bolt whose threads shear, and not the thread in the cast-iron block. This experiment shows the possibilities for the use of this

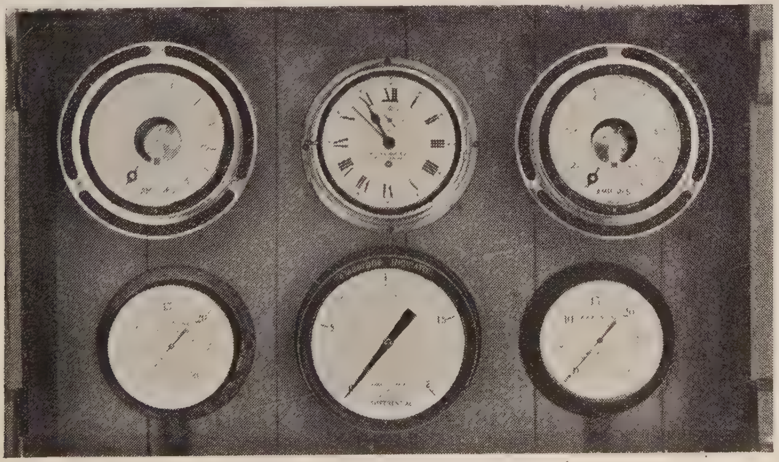

FIG. 18.—CONTROL BOARD.

iron for tool blocks and boxes where clamping bolts are constantly being used.

The third experiment (Fig. 17) shows how a good quality high-duty iron can have considerable shock resistance, and so can readily be used for operational levers in place of those formerly made in steel and malleable iron. If the test-piece as shown is made from an iron having 25 tons per sq. in. tensile strength with a very low phosphorus content, no matter how hard the bar is "jagged" with one or two hands, it will be impossible to break it.

Production Considerations

Having finally convinced his customers as to what he can make his irons withstand, the small-scale manufacturer will probably then be faced with a reaction in the opposite direction, and unless he is firm he will be persuaded to attempt to make all types of castings formerly made in cast steel and from forgings, which may be impossible. He must undertake this new work with caution lest it be to his detriment.

He has various courses open to him as to how to manufacture these new irons. He can either obtain the advice of one of the existing consultants, many of whom have done a considerable amount of pioneer work in the interest of his requirements, or he can adopt one of the proprietary methods, after he has come to a satisfactory agreement as to his capabilities with the proprietors of these processes, or finally he can attempt some of the easier grades on his own initiative, availing himself of some of the excellent foundry literature which has been published on this matter, and after becoming proficient in the easier grades he can work up to the more advanced types with confidence. It is only necessary to have reasonably efficient foundry equipment to produce these metals, and no heavy expenditure need be incurred in the earlier stages.

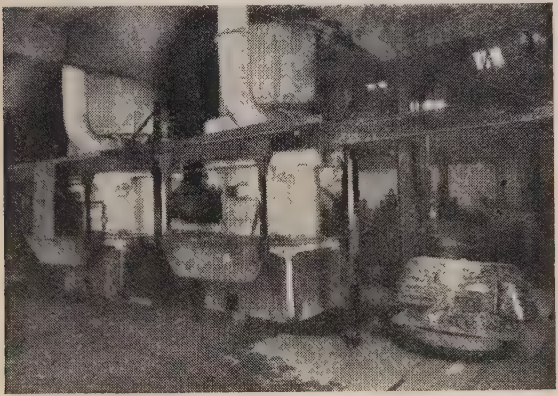

FIG. 19.—CUPOLA SLAG BATHS.

The key to correct metal melting for the production of high-duty irons is "regularity," and this is one of the main and most troublesome factors to be dealt with. This word applies to ordinary iron, but it is surprising how often the point is overlooked. It is proposed to describe briefly the method of operating the cupola to produce some of the lower grades of high-duty iron, *viz.*, those covered by British Standards Specification No. 786, grades 1 and 2.

After these grades have been made it is a simple matter for the producer to work up to the higher grades with a degree of confidence. The cupola has been chosen because it still is, and is likely to remain, the most popular and most efficient melting unit for the small foundry. Even when other types of furnaces are introduced it is most economical to charge them with molten metal already pre-heated by the cupola.

Coming back to the statement of the essentiality of regularity, a start must be made with four gauges:—No. 1 for taphole diameter; No. 2 for slope of furnace bottom in relation to taphole; No. 3 for stack diameter to ensure that every time the furnace is daubed and patched it will resume its original size, and No. 4 for height of bed above tuyeres, which is measured from the charging door after the bed has burned up prior to final charging. These four gauges should be kept in a prominent position and used daily.

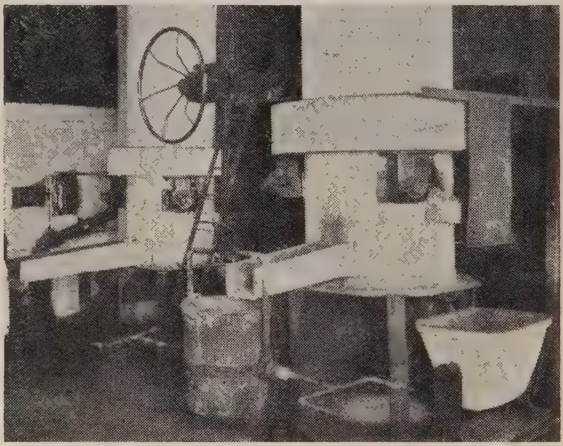

FIG. 20.—SMALL CUPOLAS.

Cupola Operation

The next point determining regularity includes materials used, including coke, limestone and air. The materials to be melted, whether pig, scrap metal or steel, should not exceed 1/3rd the furnace diameter in length, nor be less than 1/5th, nor should a flat piece of scrap exceed 1/6th the cupola area. The charge should be distributed so that the larger pieces are to the outside. The steel should be on top of the pig-iron and scrap, and any alloy addition should be in the centre. The coke should be from 4 in. to 5 in. cube. Long fingers, while indicating good coke, should be broken to these limits before charging. The volume of air is also an essential factor and is more important than pressure. The volume can be recorded by either a revolution counter in the case of positive and semi-positive blowers, an ammeter on the electrical power supply, or a Pitot tube with differential gauge in the case of all types of blowers. The blast volume should be about 14 cub. ft. per lb.

of charge melting. This is an appropriate figure dependent on many variables, including the altitude of the foundry.

While operating, the cupola must be worked in a regular manner to a timetable, the same weight being run out per tap as is charged in at the charging door at fixed time intervals. Fig. 18 shows an inexpensive cupola control board for two furnaces, with the following units:—One differential gauge for volume connected by two-way cocks to a Pitot tube in each blast main; electric-motor ammeters whose readings vary in direct relation to the blast volume; Budenberg pressure gauges, reading in in. of water (read much more clearly than orthodox water or mercury gauges); and a ship's clock which stands up well to foundry conditions.

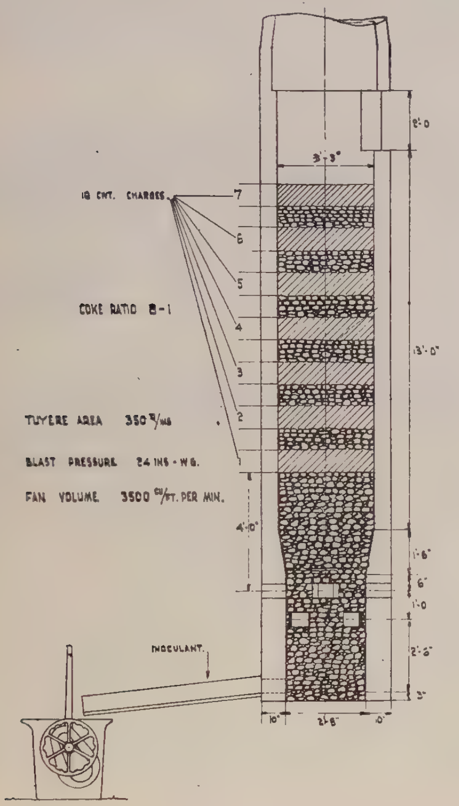

FIG. 21.—6-TON FURNACE LINES.

Once the ideal melting conditions have been attained, the readings of these gauges should be noted and preferably marked so that the conditions can be maintained. To assist good working the vicinity of the furnaces should be kept clean, and Fig. 19 shows the backs of 6-ton and 8-ton furnaces regularly producing high-duty iron. It will be noted that the slag is handled in a similar manner to that used on blast furnaces. Apart from keeping the vicinity of the furnaces clean, the chilled slag obtained can be sold to local builders.

Fig. 20 shows two small furnaces of 15 cwts. and 20 cwts. capacity, designed for the production of high-duty iron, the outstanding features being:—(1) Wind belt independent of furnace casing being supported by the tuyeres. This eliminates the possibility of wind leakage caused by burst seams through furnace distortion. (2) Wide-area tuyeres each with independent damper control.

Details of Two Furnaces

It is not proposed here to give all details of charging to cover any cupola, as each furnace has its own peculiar characteristics, but detailed charge and furnace dimensions will be given for a 6-ton and 20-cwt. furnace, both of which have been proved in constant operation. Fig. 21 shows the lines of a 5- to 6-ton per hr. furnace. It will be seen that the furnace has a fairly long stack to ensure preheating, also an ample tuyere area of about 350 sq. in.

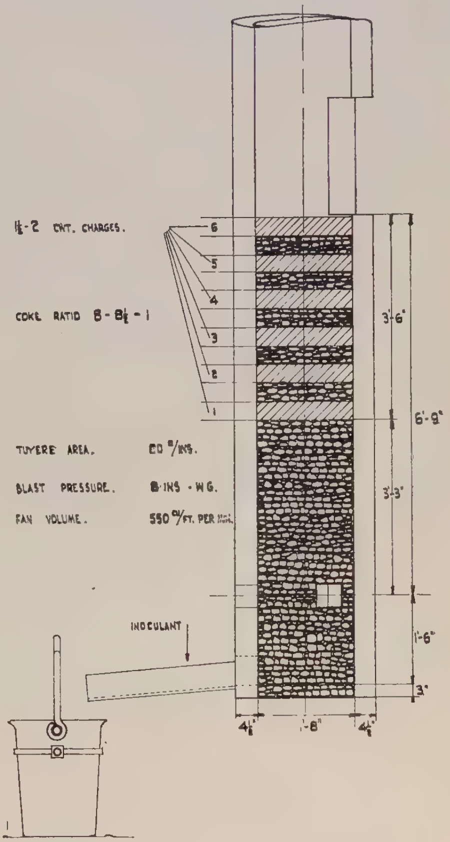

FIG. 22.—20-CWT. FURNACE LINES.

The depth of bed charge is also shown as 48 in. above the centre line of the top tuyeres. This high-bed charge assists the preheating so that the early metal tapped out is hot. The fan volume and pressure should always be on top of the maximum required and provision for checking down must be made and should be operated from a convenient position. It is important that the air volume should be kept constant by observing the meter readings and checking down accordingly, particularly during the latter end of the blow. The weight of metal per charge suggested is 10 cwts., but this can be varied till the correct charge for smoothest working is obtained.

Fig. 22 shows a 20-cwt. furnace, which is an exceptionally handy size to have in any foundry, especially the small foundry, as it enables an economical blow to be made every day and so saves the unnecessary number of box parts which are required when melting takes place only two or three times a week. The height of the bed charge in this case is 39 in. above the centre line of tuyeres, which has a total area of 80 sq. in. 550 cub. ft. of blast is required per min. at a pressure of 8 in. w.g. This low blast-pressure is advisable on small cupolas or a final iron too low in carbon will be obtained.

Composition of Irons

Take the analysis of a grade 1 or 2 high-duty iron for general work of some ½ in. to 1 in. section to be 3.0 to 3.1 total carbon, 1.85 Si, 0.12 S, 1 Mn, and 0.3 per cent. P. Lower carbon will produce a higher tensile test, but for general jobbing work it is not advisable to have the total carbon content below 3 per cent. or trouble and complications may occur beyond the scope of the small iron-founder. This silicon content can be varied to suit casting section, either by adjusting the charge or the amount of inoculant. The high sulphur content, which would have been a danger on the older types of cast iron, is associated with nearly all high-steel content melts, and can be nullified by casting hot and maintaining a manganese content at 1 per cent. by the addition of ferro-manganese or spiegeleisen to the charge. The phosphorus content should never exceed 0.3 per cent., and the lower this figure the greater the shock resistance of the final casting.

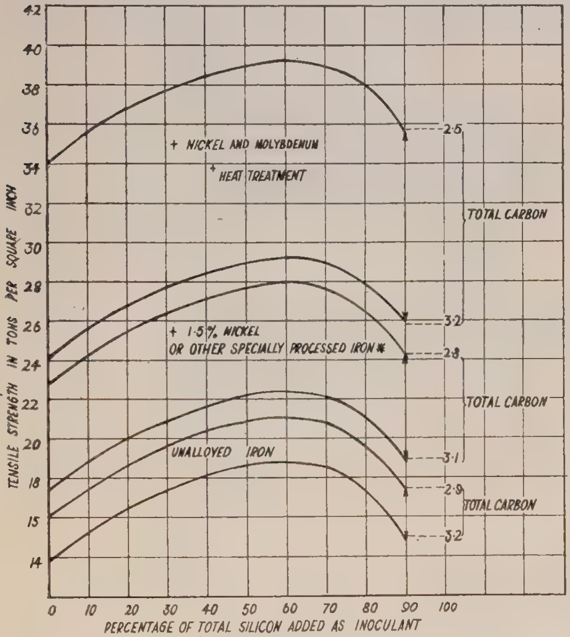

FIG. 23.—EFFECT OF COMPOSITION AND PERCENTAGE INOCULANT ON TENSILE STRENGTH. (THIS CHART DOES NOT APPLY TO IRONS PROCESSED BY OTHER INOCULANTS.)

The foundry undertaking high-duty casting should have the following metal stocks available, the analysis of the various items being given by the suppliers:—

Stock No.	Description.	T.C	Si	S	Mn	P
A	Low phos. ..	4.0	2.0	0.04	1.0	0.05
	,, ,,	3.9	2.0	0.05	1.0	0.2
B	Medium phos.	3.5	2.5	0.06	0.8	0.5
C	,, ,,	3.5	3.5	0.06	0.8	0.5
D	Steel scrap ..	0.2	0.1	0.05	0.4	0.05
E	Refined iron or shop returns	3.0	1.85	0.06	0.8	0.3

If no refined iron or return scrap is available, a virgin charge would be: 10 per cent. stock A, 40 per cent. stock B, 50 per cent. stock D, plus 1 lb. of 75 per cent. ferro-manganese per cwt. charged, and 1½ lbs. of 75 per cent. ferro-silicon inoculant per cwt. tapped. After this mixture has been established and shop returns materialise, the future charges would be: 10 per cent. stock A, 20 per cent. stock B, 20 per cent. stock E, 50 per cent. stock D, plus 1 lb. of 75 per cent. ferro-manganese per cwt. charged, and 1½ lbs. of 75 per cent. ferro-silicon inoculant per cwt. tapped. The analysis of the finished casting would be approximately as follows:—T.C 3.0 per cent. Si 1.85, S 0.09, Mn 0.9 and P 0.23 per cent., with good physical and casting properties.

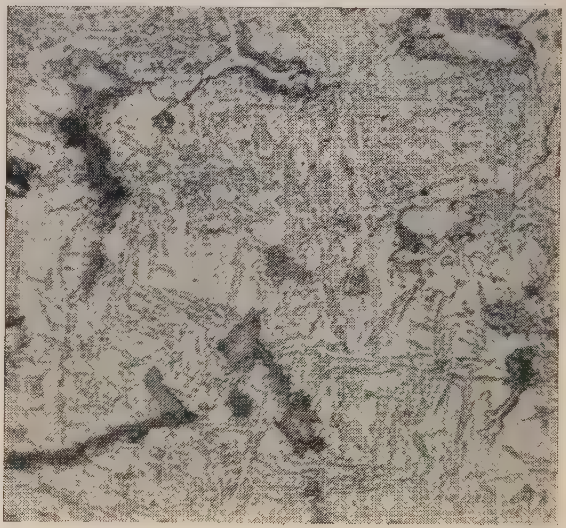

FIG. 24.—ACICULAR STRUCTURE.

Melting Losses and Inoculation

During melting, the probable silicon loss due to oxidation will be 20 per cent. and manganese loss 25 per cent.; also approximately 5 per cent. of silicon added for inoculation is lost due to deoxidation of metal. The carbon is maintained constant and free from well pick-up by tapping regularly at short intervals. The inoculation is carried out in the spout near the taphole. The melting coke required is slightly more than the normal 10 to 1 ratio, as some of the carbon is absorbed into the metal. The ratio suggested for this 50 per cent.

steel charge would be 8.5 to 1. Four per cent. of 2-in. limestone per metal charge should be placed on the coke prior to each charge.

It has been known for 70 years or more that the addition of steel to pig-iron in a cupola would produce a stronger material, so-called semi-steel, and also to raise the tensile strength of cast iron from a 9-ton tensile textbook figure to B.S. 321, Grade A, 11-ton tensile. What, then, might be asked, is the secret of the cast irons which have been produced during the last decade, which has necessitated the issue of a new British Standard Specification[5] doubling the tensile strength? This so-called secret is nothing more or less than adding ferro-silicon in crushed form to the metal stream and calling this involved and difficult procedure "inoculation."[6]

Ferro-silicon is not the only material which has this property, but for the purpose of this Paper is taken as the most convenient. It should be added in pea-size granular form to the metal stream 10 min. before the ladle is required for casting. The effect of this procedure on the molten metal is not permanent, and after 15 min. the effect rapidly begins to wear off.

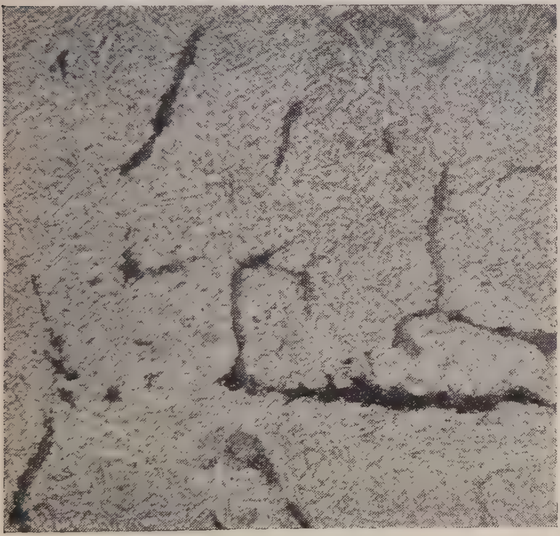

FIG. 25.—ACICULAR STRUCTURE TEMPERED.

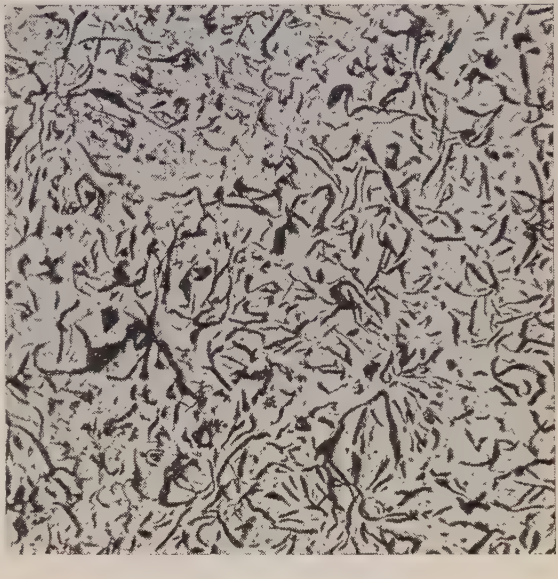

FIG. 26.—GRAPHITIC DISTRIBUTION.

The foregoing has described in a brief manner the procedure which would be adopted for the satisfactory production of high-duty grey iron, and, provided these instructions are followed in a reasonable manner and the metal melted hot and regular, no difficulty should be experienced in meeting the necessary specifications. Indeed, after the foundry has been running regularly on this metal and has become permeated with high-duty metal in the shop returns, it will be found practically impossible to produce an iron in the lower 9-ton tensile range.

If the double of B.S. maximum specified strength has been achieved in less than a decade, one is justified in asking what is going to happen in the future. Is this phenomenal advance going to continue or is there going to be a lull in development? From current facts, this progress is accelerating.

Fig. 23 shows the effect of different inoculation percentages on different groups of cast iron. It will be seen that present knowledge shows that in various groups of iron the addition of approximately 60 per cent. of the silicon content as an inoculant produces the strongest iron.

Group A represents the irons whose methods of production have just been described in some detail. This group meets grades 1 and 2 in the B.S.S. 786. Group B, which is produced in a similar manner, but may have less total carbon present and also may contain a small percentage of alloy in the form of nickel or some other metal, will meet the highest B.S.S. at present published, *viz.*, B.S. 786 grade 4. Group C, which, it will be noted, reaches a tensile strength of nearly 40 tons, is not a hypothetical case, but has been achieved. R. A. Flinn and D. J. Reese[7] have obtained 44.3 tons tensile with an iron of 2.3 per cent. T.C, 2.31 Si, 1.03 Ni and 1.36 Mo, heat-treated for 5 hrs. at 370 deg. C.

Acicular Irons

This new development in high-duty grey-iron research is being conducted simultaneously in England and America on slightly different lines. Two excellent Papers have been presented describing these developments by Flinn and Reese[5] and McRae Smith.[8] This type of high-duty iron is known as acicular or pseudo-martensitic iron; it has the following remarkable properties: Heat-treatment need not exceed 370 deg. C., *i.e.*, which can be carried out in the average foundry stove; Brinell hardness of 350 with machinability, *viz.*, 8 in. per min. milling with 18 per cent. tungsten cutters; tensile strength and yield point of 30 tons upwards; Izod shock resistance more than five times that of common cast iron; abnormal heat and crazing resistance.

Fig. 24 shows this acicular structure in the "as cast" condition consisting of needles of ferrite in a ground mass of austenite. After tempering at 320 deg. C. for several hours, the tensile strength is increased and a structure similar to that shown in Fig. 25, consisting of ferrite needles in a ground of decomposed austenite, is obtained. American practice up-to-date has favoured a tempering heat of 370 deg. C. to obtain the best results, while in this country 320 deg. seems to have been the chosen temperature.

The writer has attempted the production of these acicular irons on a commercial scale and has obtained some very good results. Concentration has been made on a total carbon range of 3/3.1 to render this iron adaptable for general foundry conditions. Experimenting still further an iron was produced with a total carbon content of 3.4, and even with this high carbon content 23 tons tensile was obtained on a 1-sq. in. section test-bar.

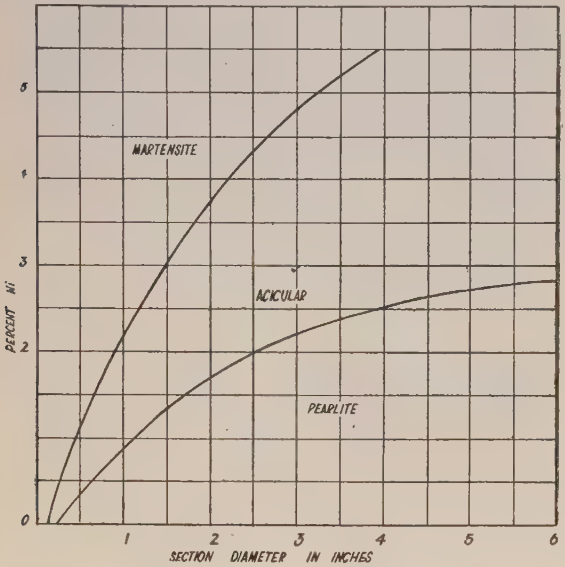

FIG. 27.—EFFECT OF NICKEL CONTENT IN RELATION TO CROSS-SECTION ON STRUCTURE.

Fig. 26 shows the graphite distribution of this test-bar under 50 magnifications. The extremely curly and interlocking nature of the graphite, which is a characteristic of acicular irons, will be noted. The acicular range is sandwiched in between the pearlitic and martensitic, and accordingly close control of the nickel content in relation to the cross section of the casting is necessary to obtain the acicular structure clearly defined. Fig. 27 shows the effect of nickel content in relation to cross section as depicted by Flinn and Reese,[5] whilst Fig. 28 shows this range considerably reduced in the light of the author's experience on certain castings.

In view of the above it will be apparent that it is imperative that the general metal thickness of the castings to be produced should be constant and that only one casting section can be run in the foundry without changing the metal analysis.

The first-named apparent drawback can be overcome by foundry co-operation with the design department, whilst the second drawback is overcome by foundry controlled planning.

Importance of Design

A word of warning to designers would not be out of place, suggesting that castings should not be asked for in a higher grade than is necessary to meet the purpose required with an adequate margin of safety, as the higher the physical properties required so the greater the difficulty in casting production, and it is not economical to specify a 30-ton iron with valuable alloys when a sound 20-ton iron will fill the bill.

It will be seen from this Paper, which has sketched the advance in grey iron in a simple and non-technical manner, that recent progress has been phenomenal, and while being used in many cases to further the war effort,[9] offers remarkable post-war opportunities. The foundry can do the job, but the engineer who is the consumer calls the tune, and must have these developments presented to him in an acceptable manner. Several individual attempts by certain concerns have been made with considerable success to publicise the merits of high-duty grey irons; surely this should not be left to one or two individuals, but should be the obligation of the original producer of pig-iron, *viz.*, all the pig-iron manufacturers acting as one body.

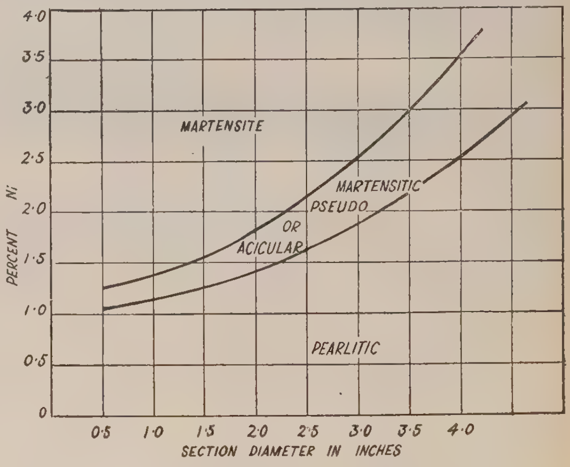

FIG. 28.—EFFECT OF NICKEL CONTENT IN RELATION TO CROSS-SECTION ON STRUCTURE (REVISED).

The author wishes to thank the firms who have contributed some of the excellent photographs, *viz.*, Craven Bros. (Manchester), Limited (Fig. 1), Wm. Asquith, Limited (Figs. 2, 4 and 5), International Meehanite Metal Company, Limited (Figs. 3, 6 and 14), Swift Summerskill & Company, Limited (Fig. 7), Worthington Simpson, Limited (Figs. 8 and 9), and Glenfield & Kennedy (Figs. 10, 11, 12 and 13), and also the friends who have kindly assisted him with their suggestions and information.

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[5] British Standard Specification No. 786.

[6] Influence of Ladle Additions on the Properties of Cast Iron. E. Piwowarsky, "Foundry Trade Journal," May 2, 1940, p. 325; May 9, p. 350; May 16, p. 365.

[7] The Development and Control of Engineering Grey Cast Irons. R. A. Flinn and D. J. Reese, "Foundry Trade Journal," Jan. 8, 1942, p. 19; Jan. 15, p. 37; Jan. 22, p. 53.

[8] Melting and Casting Problems in the Production of High Strength and Special Duty Alloy Iron Castings. A. E. McRae Smith, Proc. I.B.F., Vol. XXXIV, 1940-41, pp. 73-99.

[9] The extended uses of Cast Iron with Special Reference to War Conditions. J. G. Pearce, "Foundry Trade Journal," June 13, 1940.

DISCUSSION

Cast-Iron Tool Shanks

DR. A. B. EVEREST opened the discussion by congratulating the author on a very practical Paper, and said he was specially interested to notice the warning given by the author that tungsten carbide tips were not satisfactory with electric-resistance tipping machines. He personally had come across more than one case in which cast-iron shanks were being discredited owing to failure resulting from wrong manipulation in tipping. On the other hand, where muffle tipping was used, the cast-iron shanks were giving excellent results.

He was also particularly interested in Fig. 23, showing the effect of inoculation. It appeared from this diagram that 60 per cent. of the silicon content in the final castings should be added as an inoculant to get the best results. That was a higher figure than had been thought of hitherto, but it was very important from the point of view of heavy section work. A point to be remembered here, however, is that there is a definite limitation on the amount of material which can be added to the ladle without chilling the iron too much, but the line of development indicated in the Paper gave an interesting and valuable pointer.

Dr. Everest stated that he was not very happy about Fig. 28, which showed a definite discrepancy with work published in the U.S.A. This may be due to a question of definition, since it appeared in some of the later literature that a wider type of structure was defined as acicular than had been the case in this country. There was also the obvious discrepancy in the shape of the curves, but this may be due to other factors not yet fully understood.

In conclusion, Dr. Everest stated that he felt apologetic on speaking of this Paper, since it was practical rather than theoretical. There were several practical founders present, some of whom were producing castings up to 45 tons tensile strength, and he thought that their views would be of more value to the meeting.

MR. BLAKISTON, in reply, thanked Dr. Everest for his remarks concerning the Paper, and, referring to the apparent discrepancy between Figs. 27 and 28, said that probably the former was based on tests taken on a round test-piece. In Fig. 28 the test-pieces were taken from casting sections, representing a case where it was practically impossible to produce an intricate casting of absolute constant section. This fact would automatically narrow the range wherein the acicular structure could be regularly obtained, so that portions cut from the different parts of the casting would not show structural variation.

Case of Grade I Irons

MR. P. A. RUSSELL, B.Sc., remarking that he fully agreed with everything the author had said with regard to the applications and future development of high-duty grey iron, said a great deal of stress had been laid on the composition of the iron when meeting Grades 1 and 2. Personally, however, he did not consider it necessary to use 50 per cent. of steel scrap and an inoculant to meet Grade 1, and it was hardly necessary to do so to meet Grade 2. It should be realised that Grade 1 could easily be made from irons found in this country without the specially low phosphorus of 0.3 per cent. to which the author referred, and Grade 2 could be made with iron containing up to 1 per cent. phosphorus. That was an important point at the moment. It was perhaps unfortunate that Grade 1 had been included in the specification. There had been a great deal of argument about it, and it was included largely because it was not possible to find a name for anything better than Grade A321. It might have been better to have included it with the ordinary grey-iron castings, because he did not think it was sufficiently realised what an enormous proportion of present-day castings did meet Grade 1, B.S.S. 786. Grades A and C, in the engineering world, were almost obsolete. He considered the point he was making was of national importance at the present time, but as regards the development of these high-duty cast irons, he was in entire agreement with the author, and he particularly liked the author's shock test.

The AUTHOR said he was in entire agreement with what Mr. Russell said with regard to the inoculant for Grades 1 and 2, and it was possible to produce irons to meet these grades in a much cheaper manner than he had enumerated, but this Paper was written with the sole purpose of giving a starting off point for those interested in the higher grades of grey iron. As regards the 0.3 phosphorus content, this was kept low for shock resisting castings, and Mr. Russell would agree that where the demands required considerable shock resistance it was necessary to keep the phosphorus low, and where high-duty grey iron was used to replace steel castings the shock resisting factor was always prominent.

MR. RUSSELL said he agreed that the phosphorus should be kept low for shock resisting properties, but what he rather objected to was the general statement that in order to meet Grades 1 and 2 the phosphorus must be kept below 0.3.

The AUTHOR remarked that he thought Mr. Russell and himself were in agreement.

MR. R. H. BROWN, commenting that the Paper was almost self-explanatory, asked for some details of the control board, and inquired what distance it was away from the furnace, as he rather anticipated variations in the readings if the distance was considerable.

The AUTHOR replied that the control board was a considerable distance from the cupola, a matter of 30 ft. The bore of the tube of the differential gauge was ⅜ in. dia., but there was no flow through that tube at all. The tubes of the Budenberg gauges were the same diameter, and again there was no flow through them. The air was more or less static. There was a lag of a few seconds on the gauge, but as the air was more or less static in all the tubes he did not think the diameter mattered at all. The metallurgist every week inspected the nozzle of the Pitot tube to see that no obstruction was lodged in it.

Disposition of Charges

MR. J. F. STANIER said that as the owner of a modest foundry he very much appreciated this Paper. He had never realised that such things could be done in a small shop, and he thanked the author.

MR. G. L. HARBACH, referring to the statement in the Paper that in cupola operation the steel should be on top of the pig-iron and scrap, and any alloy addition should be in the centre, said he was a little doubtful as to whether this really mattered. Considering that the steel would probably melt, not by carburisation from the coke, as was generally understood years ago, but rather from the liquid iron dripping on to the steel and carburising it in that way, would not it be more logical to expect the steel to be at the bottom of each charge instead of at the top, if each charge was to be kept separate?

Later on in the Paper it was stated "The carbon is maintained constant and free from well pick-up by tapping regularly at short intervals." He was quite aware that it was the popular idea to get it out of the well as soon as possible, but his own experience indicated that it did not matter how long it remained in the well, as there was very little, if any, carbon pick-up. The carbon pick-up took place whilst the metal passed the tuyeres, and he did not think it was increased very much afterwards. Finally, he asked what was the tapping temperature in the case of a 15-cwt. furnace.

The AUTHOR replied that the position of the steel in relation to other portions of the charge had an influence on the final carbon figures. Any alteration in the position of the materials of the charge definitely affected the final analysis of the metal. This however depended on the individual cupola peculiarities. On small cupolas the effect was more marked, and it was also found that the small furnace melted at a much lower carbon content in the final iron than did the big furnace. The regular tapping, apart from the carbon pick-up consideration, the theory of which may be right or wrong, was also advisable on account of maintaining regularity in the melting operations. The tap temperature was round about 1,450 deg. C., and in a jobbing foundry there are always a few moulds for certain components which require cooler irons and for which a high carbon content associated with preliminary taps was immaterial.

The CHAIRMAN (Mr. Daniel Sharpe, Junior Vice-President), proposing a vote of thanks to the author—which was cordially given—expressed the hope that some of those with small foundries and desiring to come into the high-duty iron picture, would feel they had an incentive to start right away and endeavour to produce the type of article that was going to be sold in the future.

Paper No. 753

Reports on Low-Tin and Tin-Free Bronzes and Brasses

By MEMBERS OF THE NON-FERROUS SUB-COMMITTEE OF THE TECHNICAL COMMITTEE

Foreword

In consequence of the present need for economy in the consumption of tin, the Non-Ferrous Sub-Committee has had under consideration the use in the foundry of alloys free from tin or containing lower percentages of tin as substitutes for Admiralty gunmetal and similar bronzes. Guidance was sought from the Sub-Committee by Government Departments on this matter, with particular reference to the possibilities of producing castings in alloys lower in tin than has been customary, and of making greater use of cast brasses that can be made from available scrap.

Concurrently the British Standards Institution has given consideration to the same matter, and has drawn up War Emergency Specifications for two additional gunmetals, for two grades of cast brass, a silicon-bronze and an aluminium-bronze. These new specifications have now been issued and are as under:—

B.S.S. 1021/2 88/8/4 Gunmetal Ingots and Castings.
B.S.S. 1023/4 86/7/5/2 Gunmetal Ingots and Castings.
B.S.S. 1025/6 Brass Ingots and Castings, Type A.
B.S.S. 1027/8 Brass Ingots and Castings, Type B.
B.S.S. 1029/30 Silicon Bronze Ingots and Castings.
B.S.S. 1031/2 Aluminium Bronze Ingots and Castings.

It is necessary that every consideration should be given to the substitution, wherever this is practicable, of one or other of these alloys for a material high in tin content. It is proposed by the British Standards Institution, and by the Government Departments concerned, that for the duration of the war the use of Admiralty gunmetal of the 88/10/2 type (B.S.S. 382/3) should be severely restricted, that leaded gunmetal of the 87/9/3/1 type (B.S.S. 900/1) should not be used, and that the alternative alloys prepared as far as possible from scrap should be substituted. Supplies of scrap will not, however, suffice to produce all the gunmetal required, and it is, therefore, proposed that, when virgin metals are used, gunmetals of the 88/8/4 type be made. Further details of the recommendations made by the British Standards Institution in regard to the types of use to which the new alloys should be put will be found in the foreword to B.S.S. 1021-8.

One of the major points raised during the Sub-Committee's discussions concerned the foundry characteristics of the silicon bronzes. It was felt that, while good-quality castings could readily be produced by experienced foundries in these alloys, some difficulty might be met by those not accustomed to their use. It was not felt possible, therefore, to make general recommendations for the substitution of silicon bronzes for tin bronzes, but it was thought desirable to have some authoritative guidance on foundry technique made available to such foundries as might consider the casting of silicon bronzes. Accordingly, a small panel appointed by the Sub-Committee, comprising Mr. M. C. Oldham, Dr. W. O. Alexander and Mr. G. Elston, kindly undertook to draft such recommendations. The report of this panel forms the basis of the accompanying Paper on "Silicon Bronzes as Casting Alloys," and the Sub-Committee wishes to place on record their indebtedness to the three gentlemen concerned for their co-operation and assistance.

As a further guide to the properties and applications of the low-tin bronzes and brasses, Mr. F. Hudson has compiled a comprehensive review of the literature on this subject, and his Paper on "Properties of Sand-Cast Low-Tin Content Gunmetals and Brasses" follows the report on the silicon bronzes.

Thirdly, two other members of the Sub-Committee, Mr. J. Arnott and Mr. E. J. L. Howard, undertook practical tests on the foundry characteristics of the low-copper-content brass covered by B.S.S. 1028. Whereas no difficulty should be experienced with brass of Type A or of Type B, provided that the copper content is on the high side of the specification limits, it was thought possible that some difficulties might be experienced in running the Type B alloy when the copper content was on the low side, particularly with an appreciable aluminium content. In that case, moulding methods similar to those employed for the manganese bronzes would, it was thought, become necessary. A short Paper by Mr. Arnott and Mr. Howard covering this point concludes the Sub-Committee's report.

PART I.—SILICON BRONZES AS CASTING ALLOYS

Silicon bronzes have recently been made the subject of British Standards War Emergency Specification No. 1030. This specification, together with a number of other new or revised specifications, originated in the present urgent need for economy in tin and for the replacement, wherever practicable, of high tin-content bronzes by alloys free from tin or containing lower percentages of that metal.

Although the silicon bronzes are capable of giving reliable castings of good mechanical properties, it is felt that difficulties might be experienced in foundries having no previous experience of these alloys. The Non-Ferrous Sub-Committee considered, therefore, that while it was not in a position to make general recommendations concerning the use of silicon bronzes as substitutes for tin bronzes or gunmetals, it might be useful to give some guidance on foundry technique to those foundries who may contemplate producing castings in silicon bronzes.

The following notes have, therefore, been prepared on the properties of silicon bronzes and on the technique which has been found successful by those with long experience in the casting of such alloys.

Specification Requirements

B.S. War Emergency Specification 1030 gives the following limits of composition:—

Si	1.50 to 5.00 per cent.
Mn	1.50 per cent. maximum.
Zn	5.00 ,, ,, ,,
Fe	2.50 ,, ,, ,,
Total elements other than copper and those specified above	0.50 ,, ,, ,,
Cu	Remainder.

The mechanical properties called for in the specification for either separately cast or cast-on test-bars, are:—

Ultimate tensile stress, 20 tons per sq. in. minimum.

Elongation, 15 per cent. minimum.

General Casting Properties

The silicon bronzes are capable of giving close grain, homogeneous castings of high strength, toughness, good resistance to corrosion and suitability for pressure work. When molten they are very fluid, producing sharp and well-defined castings from sand moulds. They can also be cast by the centrifugal process and in chilled moulds.

Physical and Mechanical Properties

Silicon bronzes possess approximately the following characteristics:—

Density (cast)	8.4 gm. per c.c.
Weight per cub. in.	0.92 lb.
Shrinkage	$\frac{5}{32}$ to $\frac{3}{16}$ in. per ft.

In practice the mechanical strength of silicon bronzes ranks well above that obtained with the gunmetals and similar alloys in which tin is an important constituent. Standard test-pieces cast in green sand give the following average properties:—

Ultimate tensile stress, tons per sq. in.	22
0.1 per cent. proof stress, tons per sq. in.	9
Elongation per cent. on 2 in.	20
Brinell hardness (10 m.m. ball, 500 k.g. load)	90

Suggestions for Foundry Technique

Silicon bronzes may be melted without difficulty in pit fires or tilting furnaces of the coke-, oil- or gas-fired types. Melting should be carried out as quickly as possible, exposure to the furnace atmosphere being kept to a minimum. The melt may be kept well covered with a gasless flux, such as ordinary bottle glass, cryolite or sal-ammoniac. In cases where the liquid slag is very fluid, a sprinkling of dry silica sand may be used to thicken it so that it may be readily skimmed prior to casting.

The molten metal should not be allowed to remain in the furnace too long after the casting temperature has been attained. Excessive stirring or puddling during melting should be avoided, as this is not only unnecessary but tends to disturb the protecting cover, and may cause gas pockets in castings as a result of contamination of the metal by furnace gases. The metal should be stirred with a graphite stirrer or a coated iron rod. Care should be taken not to overheat the alloy.

Scrap can be added to furnace charges in the usual amounts without detriment to the castings produced. Great care should, however, be observed that no damp or oily scrap is melted in that condition. The average casting temperature is in the neighbourhood of 1,130 deg. C., this being modified as required to suit thick or thin sections. The alloy has considerable fluidity, therefore thin sections can be successfully cast.

The characteristic of all silicon bronzes is their short freezing range, approximately 50 deg. C., and shrinkage therefore takes place at a greater speed than in the gunmetals. This necessitates special attention to the feed requirements, heads and runners of generous size being required. Various moulding methods may be employed for casting silicon bronzes providing the above points receive due attention. Where the design of the castings is such that adequate feeding metal cannot be introduced, chilling may be resorted to with advantage.

As regards moulding and core making sands, silicon bronzes cast well with the usual types of sand used for other non-ferrous alloys as gunmetal, phosphor bronze and manganese bronze, and ordinary facings as lithite and plumbago give good results when used with green sand or dry sand moulds. Care should be taken, however, to ensure ample permeability, as impermeability produces skin porosity. Silicon bronze castings are clean when removed from either green or dry sand moulds, providing an unduly high casting temperature is avoided. Castings removed from the moulds while red hot will not scale unduly in the atmosphere.

Scrap Contamination

It is understood that contamination of the tin bronzes, and of gunmetal in particular, by silicon bronzes may occur in mixing machine-shop swarf, etc., and that it is particularly detrimental to the properties of remelted gunmetal. While careful supervision of scrap is the obvious solution to this problem, in the event of accidental admixture occurring, silicon bronzes can be identified from other alloys by a simple test described in the appendix.

Welding

Cast silicon bronzes are readily weldable by the autogenous acetylene or arc methods, and castings containing sand-holes or blow-holes can be salvaged readily by welding these defects. When oxy-acetylene welding, a distinctly oxidising flame should be employed, rod or wire of the same composition being employed. A suitable flux is composed of 9 parts fused borax and 1 part sodium fluoride.

SPECIFIC ALLOYS

The above general data on silicon bronzes refer particularly to P.M.G., marketed by Vickers-Armstrongs, Limited, and Everdur, marketed by I.C.I.

(Metals), Limited. It will be appreciated that, as these two alloys were developed independently, certain differences may arise in practice, and some further details of their individual properties are therefore given below.

P.M.G. Metal

The preferred composition within the specification range, and the one to which the alloy is normally supplied, is as follows:—

Si	3.0 to 4.0 per cent.
Fe	1.4 to 2.0 per cent.
Mn	1.0 per cent. maximum
P	0.1 per cent. maximum
Zn	1.5 to 2.5 per cent.
Cu	Remainder

Typical mechanical properties are as quoted under the general information for silicon bronzes: The freezing range of P.M.G. is 950 to 900 deg. C. At the higher temperature the alloy is completely fluid. During melting, a precautionary measure against oxidation is to spread charcoal over the surface of the molten metal. In all melts, a small quantity of phosphor copper, say $\frac{1}{4}$ lb. to 100 lbs., assists deoxidation. Sal-ammoniac is a good flux to use prior to casting.

Segregation of scrap, as mentioned generally for silicon bronzes, is of particular importance in reference to tin and lead contamination, which should be avoided. Iron, manganese and zinc contamination are, however, not detrimental. Repeated remelting can take place with very small melting loss. P.M.G. is particularly suitable for marine engine castings, especially those for which high test pressures are specified. Its corrosion resistance is good for general marine specifications, being superior to gunmetal against sea-water corrosion and marine atmospheres.

Everdur

The typical chemical composition of Everdur for sand castings is as follow:—

Si	3.0 to 4.0 per cent.
Mn	0.5 to 1.5 per cent.
Zn	0 to 1.0 per cent.
Impurities	0.5 per cent. maximum
Cu	Remainder.

Typical mechanical properties as cast are as follow:—

Ultimate tensile stress	23 tons per sq. in.
Elongation	18 to 25 per cent. on 2 in.
Izod impact strength	30 to 60 ft./lbs.
Brinell hardness	70 to 95

When annealed for half an hour at 700 deg. C. and slowly cooled, the following properties are observed:—

Ultimate tensile stress	22 to 26 tons per sq. in.
Elongation	22 to 30 per cent. on 2 in.
Izod impact strength	40 to 55 ft./lbs.
Brinell hardness	65 to 90

The freezing range of Everdur is 950 to 1,000 deg. C., at the latter temperature the alloy is completely fluid. In melting Everdur, it is advantageous to employ a slightly oxidising atmosphere in order to preclude the possibility of gas pick-up, and for this reason a charcoal cover to the melt must be avoided. Everdur is not unduly detrimentally affected by the presence of small amounts of the normal types of impurities. For example, the presence of lead somewhat increases machinability, while aluminium adversely affects the weldability but increases the tensile properties. Amounts of tin up to 1.0 per cent. can also be present in this alloy without giving any adverse properties. It will be noted from the typical composition that zinc may be present in moderate amounts as an intentional addition. Consequently segregation of Everdur scrap from the bronzes and brasses in order to avoid contamination of the former, while desirable, is not essential. However, as has been outlined in the general description of silicon bronzes, gunmetals are detrimentally affected by the presence of silicon.

The ductility, toughness and resistance of the metal to pressure may be improved by a simple annealing for $\frac{1}{2}$ to 2 hrs. at 700 deg. C., followed either by quenching or slow cooling. A further advantage of annealing is that casting strains may also be removed. Everdur is an alloy which was primarily developed for use in chemical manufacture, and as such has been in use for fifteen years. The alloy is therefore superior to copper in resistance to corrosive materials whether solid, liquid or gaseous. It exhibits particularly good resistance to seawater corrosion and marine atmospheres.

The heaviest casting known to have been made in this country in Everdur was a bowl for chemical plant weighing approximately 11 cwts. On the other hand, small parts made for multiple running are being produced equally successfully for aero-engine parts, a high rate of production being achieved with total rejections as low as $\frac{1}{8}$ per cent.

APPENDIX

Rapid Workshop Test for Distinguishing between Silicon Bronzes and other Bronzes and Brasses in the Form of Machine Swarf

The following simple tests have been devised to distinguish between silicon bronzes and certain other alloys, particularly gunmetal.

Nitroprusside Test

Solutions Required.—(1) 5 per cent. aqueous sodium nitroprusside solution, and (2) 5 per cent. aqueous hydrogen peroxide solution. Five volumes of 20 vol. hydrogen peroxide diluted to 100 vol. with distilled water.

Place a small portion of drillings or turnings in a test tube and cover with sodium nitroprusside solution. Hold the end of the tube over a Bunsen flame until the solution boils, and maintain for 1 to 2 min., remove the test tube from the flame, and after a few seconds decant the solution from the drillings. Wash out the test tube with tap water without removing the drillings and add a little hydrogen peroxide solution. The surface of silicon bronze drillings immediately turns dark blue in colour, while gunmetal is unaffected. This test will also differentiate silicon bronzes from 95/5 tin bronze, manganese and aluminium bronzes, and the brasses such as 97/3, 90/10, 70/30, aluminium, Admiralty and high tensile. Copper and cupro-nickel also give the reaction with sodium nitroprusside, but these are unlikely to be confused with silicon bronzes.

Ammonium Sulphide Test

A convenient and simple method of distinguishing between silicon bronzes and certain other alloys is by means of a spot test involving the use of ammonium sulphide solution. With this reagent both silicon bronzes and gunmetal give a black stain when a spot of the solution is applied, but this is not shown with brasses containing manganese, aluminium or tin, or the manganese and aluminium bronzes. Copper and (97/3, 90/10) brass give a black stain with ammonium sulphide, and this reagent is therefore best used in eliminating certain classes of material before applying the nitroprusside test.

PART II.—PROPERTIES OF SAND-CAST LOW-TIN CONTENT GUNMETALS AND BRASSES

By F. HUDSON

Emergency specifications for certain low-tin content gunmetals and cast brasses will shortly be introduced, with the view of conserving virgin metal supplies, particularly as regards tin, and to enable full use to be made of available supplies of gunmetal and brass scrap. It is hoped that engineers and founders will substitute these new specifications wherever possible for the higher tin content bronzes and gunmetals widely favoured in the past. In order to effect such a changeover intelligently and with discrimination, it is essential to have a comparison of properties and production data available, and it is hoped that the following condensed review will serve a useful purpose in this direction.

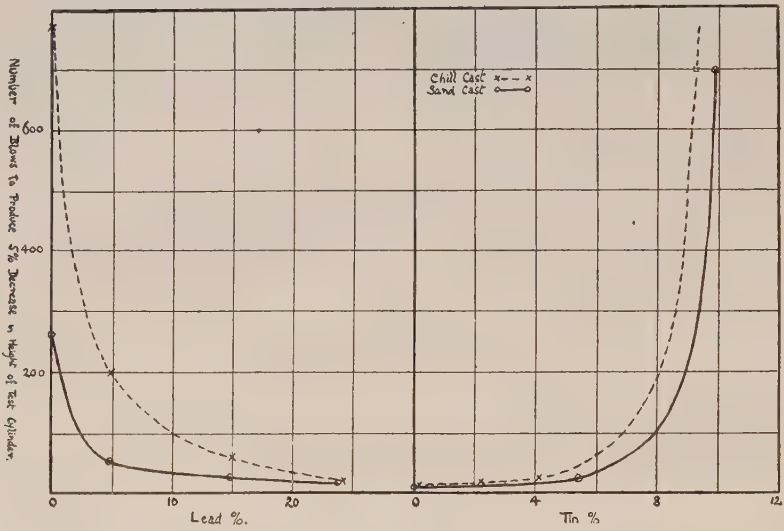

FIG. 1.—EFFECT OF LEAD AND TIN ON RESISTANCE OF BRONZE TO POUNDING AT ROOM TEMPERATURE.

(French, Rosenberg, Harbaugh and Cross. "Wear and Mechanical Properties of Railroad Bearing Bronzes at Different Temperatures." Journal of Research, Research Paper No. 13, U.S. Bureau of Standards, Vol. I, September, 1928)

Before commenting on the properties of the alloys covered by the emergency specifications, it will be appreciated that it is not possible to entirely eliminate the higher tin content alloys from engineering applications. For certain special purposes their use appears to be essential. For example, it has been shown[1] that in unlined bearings subject to pounding, such as employed for railway wagon bearings and rudder bushes, etc., on ships, the resistance to deformation is markedly reduced as the tin content falls below 10 per cent. and with the introduction of lead (see Fig. 1).

It is interesting to note that the presence of up to 4 per cent. zinc has in most instances but little effect upon frictional properties and resistance to deformation.[2] The use of gunmetal or bronze containing around 10 per cent. tin is also considered essential for the production of high-pressure air and hydraulic valves operating at 1,000 to 4,000 lbs. per sq. in. Alloys containing up to as much as 12.5 per cent. tin have been unnecessarily specified for those latter applications in the past, the higher tin content making the production of sound castings more difficult in the foundry.

On the other hand, for many purposes gunmetal of the 88/10/2 type is being wastefully employed, and service conditions can be equally well met by the use of lower tin content alloys, or even by cast brass. The subsequent comparison of properties has been specifically compiled to offer guidance in this direction.

PART I—LOW TIN CONTENT GUNMETALS

88 per cent. copper, 8 per cent. tin, 4 per cent. zinc.

86 per cent. copper, 7 per cent. tin, 5 per cent. zinc, 2 per cent. lead.

85 per cent. copper, 5 per cent. tin, 5 per cent. zinc, 5 per cent. lead.

Mechanical Properties (*Room and Elevated Temperature*).—Table I shows a comparison of mechanical properties at room temperature of the three gunmetals under consideration against Admiralty gunmetal. Table II gives the mechanical properties principally based on short-time tensile tests, at elevated temperature. Considerable work has been done by Spring,[3] of the Crane Company, U.S.A., on cast materials for high-temperature service, which shows that, whilst short-time tensile tests indicate that the higher tin content alloys of the 86/12/2 and 88/10/2 types are stronger than 86/7/5/2 gunmetal at elevated temperature, the latter alloy is actually more creep resistant than the former at temperatures above 250 deg. C. (482 deg. F.). Spring gives the following figures for creep resistance considered from the approximate limiting temperature standpoint:—

Material.	Approx. temp. permitting creep of		
	1 per cent. in 10,000 hrs. at 11.1 tons per sq. in.	1 per cent. in 10,000 hrs. at 1,000 lbs. per sq. in.	Range.
	Deg. C.	Deg. C.	
Cast red brass (5.63 per cent. Sn, 6.26 per cent. Zn, 2.71 per cent. Pb, balance Cu)	204	427	223
Cast bronze (11.98 per cent. Sn, 1.36 per cent. Zn, 0.16 per cent. Pb, balance Cu)	232	399	167

W. C. Stewart[4] publishes the following figures on creep properties:—

Material.	Temperature.		Stress (tons per sq. in.) to produce a creep rate of	
	Deg. C.	Deg. F.	0.01 per cent. per 1,000 hrs.	0.1 per cent. per 1,000 hrs.
88/10/2 gunmetal	205	400	5.0	7.0
	260	500	2.7	4.0
	315	600	1.3	2.0
90/6/2/2 gunmetal	205	400	4.0	6.0
	260	500	2.7	4.0
	315	600	1.4	1.8

It is interesting to note that the decreased tin and increased lead contents do not appear to effect creep properties appreciably. Further creep tests have been carried out on Admiralty gunmetal and 86/7/5/2 gunmetal by Bolton.[5] The alloys tested had the following composition and room temperature properties:—

	Admiralty Gunmetal A.S.T.M. Spec. B.60.	Bronze A.S.T.M. Spec. B.61.
Copper	87.6 per cent.	87.14 per cent.
Tin	10.18 ,, ,,	6.22 ,, ,,
Zinc	2.2 ,, ,,	4.61 ,, ,,
Lead	Nil	1.83
Phosphorus	Trace	Trace
Max. strength, tons per sq. in.	21.9	16.9
Elong., per cent. ..	35.4	34.3

Creep tests were carried out on the above alloys at temperatures of 260 deg. C. (500 deg. F.), 288 deg. C. (550 deg. F.) and 315 deg. C. (599 deg. F.) after being held in the creep test for periods ranging from 700 to 1,700 hrs. The specimens were also tested in tension at room temperature to determine whether long exposure at the temperature of creep testing had produced embrittlement. It was found that the 86/7/5/2 gunmetal was well suited for use up to 288 deg. C. (550 deg. F.), but not for higher temperatures. Its limiting creep strength, based on the stress to produce a rate of flow less than 0.1 per cent. in 10,000 hrs. (0.24 × $^{-}$ in. per in. per day) after the first 500 hrs. of creep test and running up to 2,100 hrs.' duration, is about 3.57 tons per sq. in. at 260 deg. C. (500 deg. F.), and a design stress of 2.23 tons per sq. in. is recommended at this temperature. At 260 deg. C. (500 deg. F.), the load-carrying ability of Admiralty gunmetal was lower than that of 86/7/5/2, and there was definite evidence of embrittlement. Bolton recommends that Admiralty gunmetal should not be used above 232 deg. C. (450 deg. F.), and suggests a design stress of 2.23 tons per sq. in. at that temperature.

Quite recently, the American Society of Mechanical Engineers[6] have indicated maximum allowable working stresses for 86/7/5/2 and 5/5/5/5 gunmetal in their Rules for Construction of Unfired Pressure Vessels (see Table at foot of page).

Bronze valves and fittings cast in 86/7/5/2 gunmetal can be employed up to 500 deg. F., whilst, if made in 85/5/5/5 material, the maximum temperature for use is limited to 400 deg. F.

Mechanical Properties (*Sub-Zero Temperatures*).—Castings show a curious difference in behaviour from wrought materials at low temperature, for whilst the strength is increased along similar lines

Maximum Allowable Working Stresses in Lbs. per Sq. In.

Material.	For metal temperatures not exceeding deg. F.								
	Sub zero.	70 to 100.	150.	250.	350.	400.	450.	500.	550.
86/7/5/2 gunmetal	6,800	6,800	6,800	6,300	5,800	5,400	5,000	4,200	3,300
85/5,5/5 gunmetal	5,500	5,500	5,500	5,000	4,500	3,500	—	—	—

to that which occurs in wrought materials, the ductility is always slightly less than that indicated at room temperature. Strauss[7] gives the following data in connection with 88/8/4 gunmetal:—

Temperature.	Tons per sq. in.		Elong. per cent. on 2 in.	R.A., per cent.
	Yield point.	Max. strength.		
20 deg. C.	8.3	17.9	31.3	36.7
−180 deg.C	13.6	20.2	15.3	24.6

It can be assumed that changes of similar magnitude will occur in regard to the other gunmetals under review. The alteration in properties with decreasing temperature may be generalised as follows:—There is an *increase* in yield point, tensile strength, hardness, endurance limit, modulus of elasticity, and compressive strength, and a *decrease* in elongation, reduction of area, and impact resistance.

TABLE I.—*Mechanical Properties of Low Tin Content Gunmetals and Cast Brasses in Comparison with* 88/10/2 *Gunmetal.*

Properties.	Gunmetal.				Cast brass.	
	88/10/2. Sn 9.5—10.5 per cent. Zn 1.5—2.5 per cent. Pb 0.50 max. Ni 1.00 max. Imp. 0.15 max. Cu Balance — —	88/8/4. Sn 7.5—8.5 per cent. Zn 3.5—4.5 per cent. Pb 0.50 max. Ni 1.00 max. Imp. 0.15 max. Cu Balance — —	86/7/5/2. Sn 6.0—8.0 per cent. Zn 4.0—6.0 per cent. Pb 1.0—3.0 per cent. Ni 1.00 max. Imp. 0.50 max. Cu Balance — —	85/5/5/5. Sn 4.0—6.0 per cent. Zn 4.0—6.0 per cent. Pb 4.0—6.0 per cent. Ni 1.00 max. Imp. 0.50 max. Cu Balance — —	TYPE "A." Sn 2.00 per cent. max. Zn Balance Pb 1.0—4.0 per cent. Ni 1.00 max. Fe 0.75 max. Al 0.01 max. Imp. 0.50 max. Cu 70.0—80.0	TYPE "B." Sn 2.00 per cent. max. Zn Balance Pb 1.0—4.0 per cent. Ni 1.00 max. Fe 0.75 max. Al 0.25 max. Imp. 0.50 max. Cu 62.0—70.0
Y.P. (tons per sq. in.)	8—10	8—10	7—9	6—8	4—6	5—7
M.S. (tons per sq. in.)	16—20	16—20	14—18	12—16	11—15	14—18
Elongation, per cent. on 2 in.	10—30	10—30	12—30	15—35	20—40	15—35
Izod impact (ft.-lbs.)	7—17	7—17	7—17	6—12	10—20	—
Brinell hardness No.	65—80	65—80	60—70	55—65	40—60	45—65
Diamond pyramid* hardness	70—100	70—100	70—80	60—70	—	—
Compressive strength (tons per sq. in., 0.001-in. defl.) ..	6—8	5—8	5—6	4—5	3—4	3½—4½
Modulus of elasticity (lbs. by 10⁶.) ..	12—14	12—14	12—14	11—13	11—14	12—14

* Diamond hardness readings on cast material are likely to be variable and this method is therefore not recommended for control purposes.

General Physical Properties.—Typical values for such properties as specific gravity, coefficient of expansion, thermal conductivity, etc., are given in Table III. So far as the gunmetals are concerned, there is little difference in general physical properties between 88/10/2 and the other types under review.

Corrosion Data.—The increased lead and zinc contents within the range of compositions covered do not appear to have much effect on the corrosion resistance of gunmetal by normal sea and fresh water. Laboratory tests show 88/10/2 to exhibit a loss in weight of 0.288 per cent. after eight weeks' immersion in sea water. Gunmetal containing 7.0 per cent. tin, 3.75 per cent. zinc, 3.75 per cent. lead, balance copper, showed a loss of 0.26 per cent. under similar conditions. Practical observations based upon equipment, such as valves, in service tend to confirm these findings. Table IV outlines further comparative corrosion tests conducted on gunmetal and bronze in fresh and sea water at 60 and 200 deg. F.

It is interesting to observe that, while an increase of temperature accelerates the corrosion of gunmetal and bronze in fresh water, the effect of hot sea water apparently reduces the rate of attack over that experienced in cold sea water, although the degree of attack is appreciably greater than that experienced in fresh water. Care should be taken when utilising gunmetals for handling softened boiler feed waters to keep the zinc content as low as possible.

Production Data

Foundry Characteristics.—Gunmetals of the 88/8/4, 86/7/5/2 and 85/5/5/5 types are no more difficult to handle in the foundry than standard Admiralty gunmetal. As a matter of fact, both 86/7/5/2 and 85/5/5/5 possess superior castability and are particularly adaptable to the production of pressure castings in large numbers. Similar pouring temperatures to those employed for 88/10/2 (1,160 to 1,180 deg. C. for test-bars) give perfectly satisfactory results with the other alloys under review, as will be observed from the test results taken from production melts, all sand cast, made by the Phosphor Bronze Company, Limited, as given below:—

Alloy.	Pouring temp., deg. C.	Yield point, tons per* sq. in.	Max. strength, tons per sq. in.	Elong. per cent. on 2 in.	Brinell hardness No.
88/8/4	1,170	9.4	19.6	37.0	78
86/7/5/2	1,160	9.1	17.4	39.0	67
85/5/5/5	1,160	9.0	15.2	29.0	61

* Taken by dividers.

Figs. 2 to 7 show the microstructure in the polished and etched condition of the above sections. Patternmakers' shrinkage for all the alloys is around $\frac{3}{16}$ in. per ft. It should be noted that there is little danger of lead segregation occurring in gunmetal containing up to 6 per cent. lead, so far as castings of average section (up to $1\frac{1}{4}$ in.) are concerned, but this point will have to be watched in heavier sections, particularly when using 85/5/5/5.

Machinability.—The machinability of 88/8/4

TABLE II.—*Mechanical Properties of Gunmetal at Elevated Temperature.*

Temperature.		Per cent. Sn 12.25 Zn 1.46 Pb 0.01 Fe 0.01 Cu 86.21 †			Per cent. Sn 10.0 Zn 2.0 Cu 88.0 *			Per cent. Sn 10.11 Zn 1.63 Pb 0.36 Cu 87.84 ‖			Per cent. Sn 5.85 Zn 5.77 Pb 2.06 Cu 86.24 †			Per cent. Sn 5.99 Zn 5.10 Pb 2.33 Cu 86.28 †			Per cent. Sn 6.22 Zn 4.61 Pb 1.83 Cu 87.14 †					Per cent. Sn 5.24 Zn 5.48 Pb 5.33 Cu 83.37 *		
Deg. F.	Deg. C.	Y.P.	M.S.	Elong.	Elastic limit.	M.S.	Elong.	Y.P.	M.S.	Elong.	Y.P.	M.S.	Elong.	Y.P.	M.S.	Elong.	Y.P.	M.S.	Elong.	Charpy impact.	Creep strength.	Elastic limit.	M.S.	Elong.
70	20	8.9	18.0	15.0	11.4	15.2	8.0	8.3	15.2	14.0	7.4	17.0	36.5	7.1	15.2	20.5	7.3	17.5	31.2	20.0	6.25	7.5	14.2	21.0
200	93	—	—	—	—	—	—	—	—	—	6.7	16.6	37.5	—	—	—	6.7	16.7	27.2	—	—	—	—	—
300	150	—	—	—	9.8	16.1	8.6	—	—	—	6.4	15.8	31.0	—	—	—	6.6	16.8	28.7	—	—	5.7	11.8	18.8
400	205	—	—	—	—	—	—	7.5	15.0	18.0	6.7	15.2	28.5	—	—	—	6.3	15.9	25.5	19.5	—	—	—	—
500	260	8.2	14.4	5.5	—	—	—	5.9	11.8	11.5	5.8	13.0	24.5	—	—	—	5.8	14.6	20.5	15.2	4.0	—	—	—
555	288	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.9	—	—	—
600	316	7.4	15.0	9.5	8.2	9.5	3.7	—	9.0	7.0	5.8	7.3	2.5	5.6	11.4	16.0	5.6	13.2	15.7	2.2	0.72	5.0	5.4	1.1
700	370	7.4	12.7	9.5	—	—	—	—	6.7	4.0	6.0	6.0	1.0	5.5	6.8	1.5	5.5	8.3	4.0	—	—	—	—	—
800	427	6.7	10.1	3.5	—	—	—	—	4.4	2.0	4.0	4.0	0	5.3	6.4	2.0	—	—	—	—	—	—	—	—
900	482	—	—	—	—	—	—	—	—	—	3.3	3.3	0	—	—	—	—	—	—	—	—	—	—	—

* Extracted from A.S.M.E.—A.S.T.M. Symposium on Effect of Temperature on the Properties of Metals, 1931.

† Extracted from Compilation of High-Temperature Creep Characteristics, A.S.M.E.—A.S.T.M., 1938.

‖ Courtesy of J. Arnott (G. & J. Weir, Ltd.).

gunmetal will be similar to Admiralty gunmetal, whilst 86/7/5/2 and 85/5/5/5 will tend to be slightly better.

Soldering and White Metalling.—All the alloys under review are readily soldered and white metalled.

Brazing and Welding.—Brazing by the usual methods should be quite successful with all the gunmetals mentioned.

Welding operations on gunmetal are difficult to conduct due to the extreme heat fragility of the alloy and the production of zinc fume. Satisfactory results are most likely to be obtained by the use of the metallic arc process, using phosphor bronze type electrodes, as made by the leading electrode manufacturers, in conjunction with preheating. With these electrodes 88/10/2 and 88/8/4 should give good results in "building up" or repair welding. In the case of gunmetals of the 86/7/5/2 and 85/5/5/5 types welding operations become increasingly difficult and it may be more practical to adopt oxy-acetylene brazing methods, using filler rods of the Sif-Bronze type. The carbon arc process could also be employed in many cases, using phosphor bronze filler rods, containing 3 to 10 per cent. tin and about 0.3 per cent. phosphorus. Again, alloys 88/10/2 and 88/8/4 should give fairly good results, but 86/7/5/2 and 85/5/5/5 types will be more difficult. In general, the success of the process depends to a large extent on the soundness of the castings, gassy castings being almost impossible to weld without the production of gassy welds. The high thermal conductivity of gunmetals frequently renders the oxy-acetylene welding process difficult.

TABLE III.—*Physical Properties of Low Tin Content Gunmetals and Cast Brasses in Comparison with 88/10/2 Gunmetal.*

Properties.		Gunmetals.			Cast brass.	
		88/10/2 88/8/4	86/7/5/2	85/5/5/5	Type A.	Type B.
Specific gravity		8.6—8.8	8.6—8.8	8.6—8.8	8.45—8.55	8.4—8.5
Weight per cub. in. (lbs.)		0.314	0.314	0.314	0.30	0.30
Coefficient of expansion	20—100 deg. C.	17.5	17.7	17.8	17.9	19.4
	20—200 deg. C.	17.6	17.9	18.1	18.4	20.5
	20—300 deg. C.	17.9	18.2	18.4	19.0	21.8
	20—400 deg. C.	18.0	18.4	18.7	19.6	—
	20—500 deg. C.	18.1	18.6	19.0	20.2	—
Thermal conductivity .. .. Electrical resistivity		Approx. 13—15 per cent. of that of copper at 20 deg. C.			Approx. 18—22 per cent. of that of Cu at 20 deg. C.	Approx. 16—20 per cent. o that of Cu at 20 deg. C.

Applications.—Examples of suggested applications for the modified gunmetals are outlined in Table V.

PART 2.—CAST BRASSES (TYPES A AND B)

Mechanical and Physical Properties.—The mechanical properties at room temperature are included in Table I. Cast brasses types A and B are not recommended for use at elevated temperatures and there is no published data available of their mechanical properties. The general remarks on mechanical properties at sub-zero temperatures given for gunmetals can be applied to the cast brasses. The effect of low temperatures is not likely to cause any serious change in

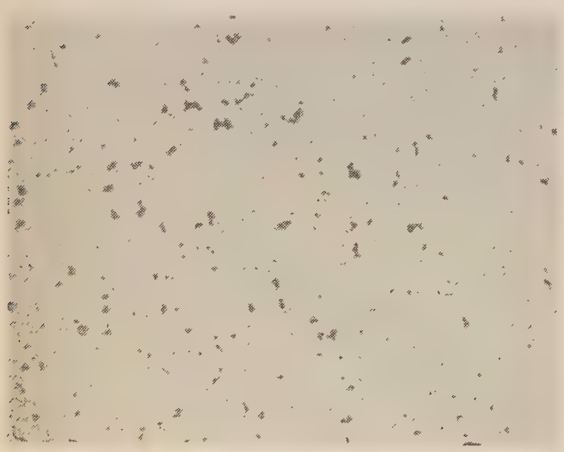

FIG. 2.—UNETCHED.

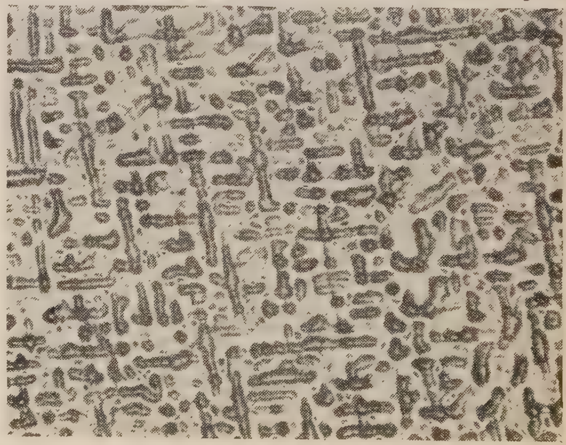

FIG. 3.—ETCHED.

FIGS. 2 AND 3.—GUNMETAL (SC1), 88 PER CENT. CU, 8 PER CENT. SN, 4 PER CENT. ZN. (× 50.)

mechanical properties, apart from some reduction in ductility. For their general physical properties see Table III.

Corrosion Data

In general, the corrosion resistance of these alloys in sea water is not quite so good as the gunmetals, but in contact with petrol or fuel oils containing sulphur their resistance is much greater. Care must be taken when applying the cast brasses to industrial applications to prevent the possibility of "dezincification" arising. This is best avoided by the use of alloys containing not more than 20 per cent. of zinc and in addition the presence of at least 0.03 per cent. of an inhibitor, either arsenic, antimony or phosphorus.

Lines[8] recently established corrosive conditions that resulted in complete "dezincification" of 0.35-in. dia. plain 70/30 and Naval brass rod in a period of 10 weeks. Under similar conditions the same alloys, modified by about 0.03 per cent. of arsenic, antimony or phosphorus, did not dezincify nor did corrosion progress along grain boundaries.

The test results on the uninhibited Naval brass are of interest. It is fairly well established that the 1 per cent. of tin associated with this alloy

TABLE IV.—*Corrosion of Cast Bronze, Gunmetal and Brass in Fresh and Sea Water at 60 and 200 deg. F.*

Alloy.	Loss in grammes per sq. m. per 24 hrs.			
	Tap water.		Sea water.	
	60 deg. F.	200 deg. F.	60 deg. F.	200 deg. F.
Admiralty manganese brass	0.27	0.43	1.19	2.00
Gunmetal (85/9/2½/3½)	0.14	0.28	1.23	0.75
Cast phosphor bronze	0.09	0.11	1.20	0.64
Cast 90/10 bronze ..	0.14	0.19	0.87	0.71

FIG. 4.—UNETCHED.

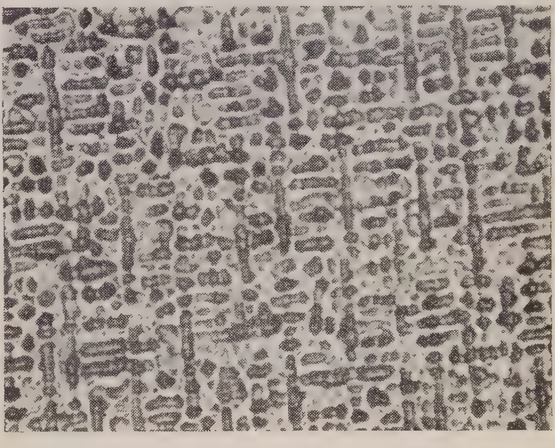

FIG. 5.—ETCHED.

FIGS. 4 AND 5.—GUNMETAL (SC2), 86 PER CENT. CU, 7 PER CENT. SN, 5 PER CENT. ZN, 2 PER CENT. PB. (× 50.)

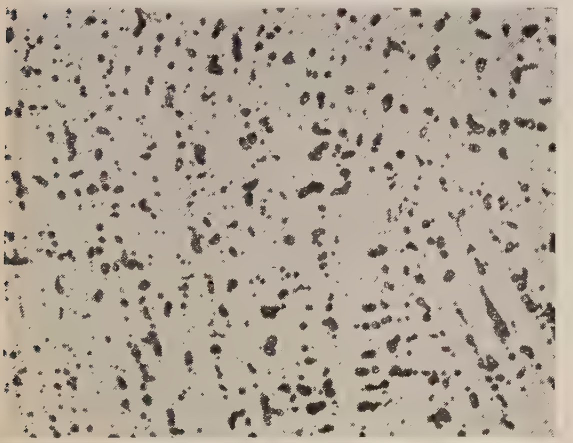

FIG. 6.—UNETCHED.

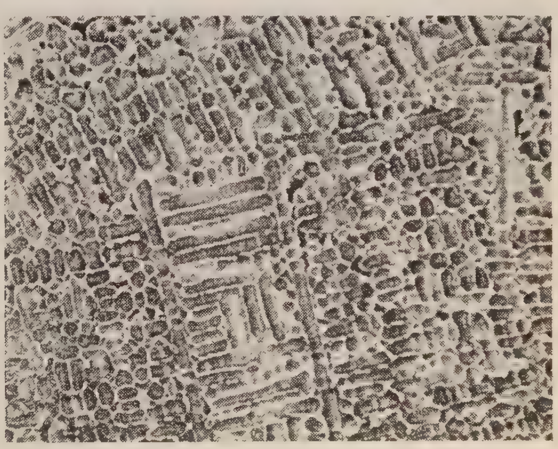

FIG. 7.—ETCHED.

FIGS. 6 AND 7.—GUNMETAL (SC3), 85 PER CENT. CU, 5 PER CENT. SN, 5 PER CENT. ZN, 5 PER CENT. PB. (× 50.)

is a retardant of "dezincification." The results of Lines' work are in agreement with this statement when temperatures of around 70 deg. F. are involved. At 150 deg. F., however, it was found that tin was without influence on the rate of the dezincification reaction. Dezincification is encountered with corrosive water supplies in plumbing work with alloys such as Muntz metal, containing 60 per cent. copper, 40 per cent. zinc and with brasses containing 67 per cent. copper, 32.5 per cent. zinc, 0.5 per cent. lead. It is particularly serious at hot water temperatures, resulting in some cases in very short life of the installation. In condenser tube applications for marine power plants and the oil industries, dezincification occurs with Naval brass containing 70 per cent. copper, 1 per cent. tin and 29 per cent. zinc.

In view of the foregoing remarks, it will be advisable to utilise cast brass, type A, for those castings required to resist corrosion, keeping composition as far as possible to the 80 per cent. copper end of the specification, and to include preferably 0.03 per cent. phosphorus, as an inhibitor. The presence of around 1.0 per cent. tin will also be of benefit in minimising corrosion. Cast brass, type B, should be reserved for applications not subject to corrosion or where a protective coat of paint can be readily applied.

Production Data

Founding Characteristics.—Cast brass, type A, has good castability, and is not difficult to handle in the foundry. It is suitable for small pressure work and the best results are obtained in this direction at the 80 per cent. copper end of the compositional range. The presence of tin and lead assists the production of sound castings, but care must be taken to exclude aluminium as far as possible. Over 0.01 per cent. of this element will

TABLE V.—*Suggested Applications of Gunmetals and Cast Brasses.*

Type composition.	B.S.S. No.	Suggested application.
Gunmetals.		
88/10/2	383	To be used only for special applications, *i.e.*, high-pressure hydraulic and air valves working between 1,000—4,000 lbs. per sq. in., control and stop valves, steering gear telemotor cylinders. Special unlubricated bearings subjected to pounding, vibration and corrosion, *e.g.*, rudder post liners and bushes, steering gear bearings, etc.
88/8/4	—	Suitable for conditions of service intermediate between those specified for alloys of 88/10/2 and 86/7/5/2 type, *e.g.*, hydraulic valves working between 500—1,000 lbs. per sq. in. (Does not possess much advantage over alloy of 86/7/5/2 type so far as steam service is concerned.) Sea cocks and other valves connected direct to hull below water-line.* Pump impellers. Stern tubes.
86/7/5/2	—	Suitable for all general-purpose castings subject to medium steam pressures (above 100 lbs. per sq. in. working pressure) and at temperatures not exceeding 500 deg. F. (260 deg. C.), *e.g.*, small engine control and boiler stop valves, cylinder cover bushes, neck rings, centrifugal pump casings, tail shaft liners and stern tube bushes. Hydraulic valves operating between 200—500 lbs. per sq. in. pressure. Suitable for high-grade backings of lined bearings. Slip rings for electrical equipment (under 2 per cent. lead if possible).
85/5/5/5	898	Suitable for general-purpose castings subject to steam up to 100 lbs. per sq. in. working pressure and temperatures not exceeding 400 deg. F. (205 deg. C.) and water pressures up to 200 lbs. per sq. in. working pressure, *e.g.*, screw down valves, bulkhead and deck fittings, tee-pieces, etc., handling auxiliary steam heating services to galleys, pantries and thermo-tanks. Cocks, taps and sanitary fittings handling sea water, *e.g.*, pump-type lavatory valves. Pumping, flooding and draining valves not directly connected to hull below water-line. Sluice valves to sea cocks. Fire hose connections. Centrifugal pump casings. Suitable for well-supported backings of certain lined bearings, *e.g.*, small stern tube bushes, etc.
Cast brasses.		
Type A (70—80 per cent. Cu)	—	Suitable for low-pressure fittings working under mildly corrosive conditions (not recommended for use at elevated temperatures or for conditions requiring exceptional wear and tear), *e.g.*, cocks, taps, pipe connections and sanitary fittings for use in fresh water at pressures up to 100 lbs. per sq. in. Ventilating valves. Name plates. Lubricators. Better resistance to oils containing sulphur than gunmetal, therefore can be used with advantage for valves and fittings handling fuel oil and petrol.
Type B (62—70 per cent. Cu)	—	Non-pressure structural and ornamental castings. Pressure gauge and telegraph cases. Voice pipe fittings and connections. Funnel fittings. Hand wheels. Gear case covers. Steering wheel brackets. Porthole and skylight casings. Motor-boat deck fittings. Bearing backings where a copper alloy is required and the backing need not in itself possess bearing properties.

* The use of cast aluminium bronze is more suitable, as there is no galvanic action between this alloy and steel in the presence of sea water.

Type.	Composition.							Pouring temp. deg. C.	Yield* point tons per sq. in.	Max. strength tons per sq. in.	Elong. per cent. on 2 in.	Brinell hardness No.
	Cu	Sn	Pb	Fe	Al	Ni	Zn					
A ..	72.15	0.40	4.71	0.42	nil	0.47	21.85	980	6.8	15.0	23.0	66
A (1)	70.25	0.33	2.45	0.36	nil	0.11	26.50	960	4.8	13.2	42.0	68
B ..	63.64	0.27	2.80	0.19	0.03	0.10	32.97	960	5.4	16.3	39.0	63
B (2)	63.80	1.22	2.93	0.35	nil	0.14	31.56	960	6.4	15.5	17.0	87

* Taken by dividers: (1) Sample 5BA, Figs. 8 and 9. (2) Sample 4BB, Figs. 10 and 11.

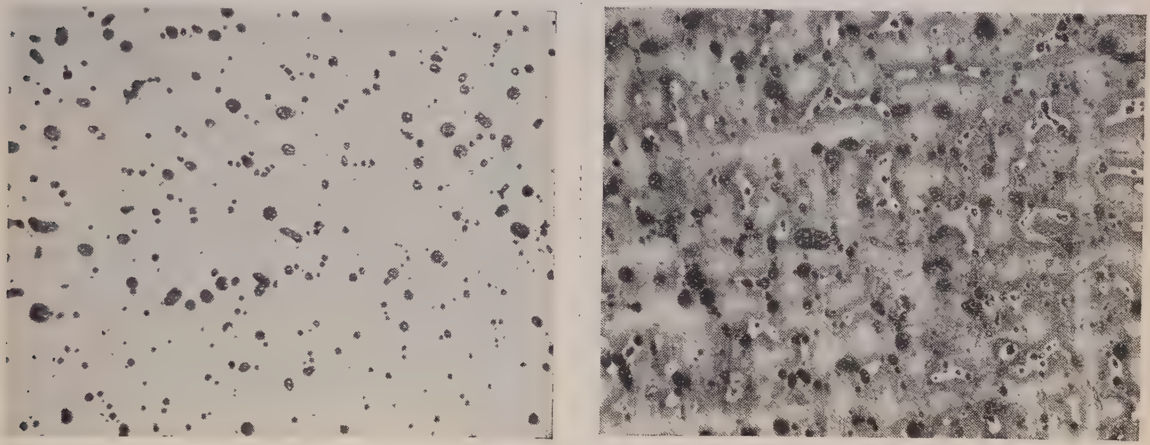

FIG. 8.—UNETCHED. FIG. 9.—ETCHED.

FIGS. 8 AND 9.—CAST BRASS TYPE A (5BA) 70—80 PER CENT. CU, 2 PER CENT. SN MAX., 1 TO 4 PER CENT. PB, 0.75 PER CENT. FE MAX., 0.01 PER CENT. AL MAX., BALANCE ZN. (× 50.)

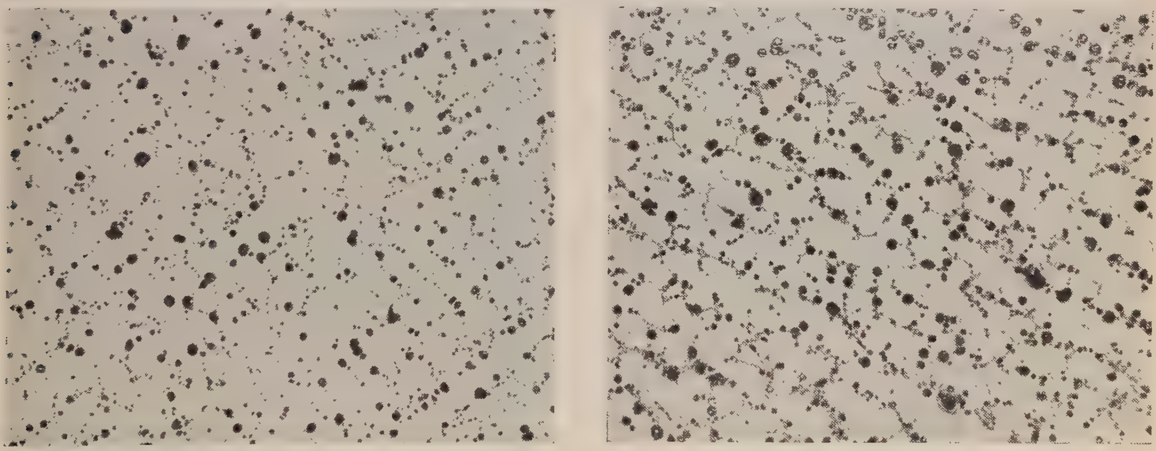

FIG. 10.—UNETCHED. FIG. 11.—ETCHED.

FIGS. 10 AND 11.—CAST BRASS TYPE B (4BB) 62—70 PER CENT. CU, 2 PER CENT. SN MAX., 1 TO 4 PER CENT. PB, 0.75 PER CENT. FE MAX., 0.25 PER CENT. AL MAX., BALANCE ZN. (× 50.)

Half-tone constituent in Fig. 11 appears to be delta caused by the presence of 1.22 per cent. tin. If this should form a continuous network the brass will become extremely brittle, particularly at the 62 per cent. copper end of the compositional range. Care should therefore be taken not to exceed about 1.2 per cent. tin, otherwise the required elongation will not be obtained.

produce excessive porosity. The production of brass castings also entails the use of more permeable moulds than used for gunmetal, particularly as regards green-sand work. Gating and feeding methods required are similar to gunmetal.

Cast brass, type B, is more difficult to handle, particularly as the 62 per cent. copper end of the compositional range is approached. As most of the supplies of this material will be obtained from scrap, it is possible that manganese will also be present from time to time, and it will, therefore, be advisable to handle this alloy in the foundry along similar lines to manganese bronze, taking the precaution of providing heavier gates and risers than one would normally allow for gunmetal. The presence of maximum tin and aluminium contents allowed will tend to aggravate troubles due to the above, and promote brittleness (see Fig. 11 and footnote).

Test-bars taken from production melts by the Phosphor Bronze Company, Limited, gave the results in the Table on page 79.

A guide to suitable pouring temperatures is as follows:—

Section of casting.	Pouring temperature.	
	Type A.	Type B.
	Deg. C.	Deg. C.
Light	1,200—1,100	1,150—1,050
Medium	1,100—1,050	1,050—1,000
Heavy*	1,050—1,000	1,000—970

* Range for test bars.

Patternmakers' shrinkage will vary from $\frac{3}{16}$ in. per ft. for cast brass, type A, up to $\frac{1}{4}$ in. per ft. for type B. Typical microstructures in the polished and etched condition of both the types of cast brass under review are shown in Figs. 8 to 11.

Machinability.—The machinability of both types A and B cast brass is excellent.

Soldering and White Metalling.—Both the cast brasses under review are readily soldered and white metalled, even with the maximum allowed aluminium content of 0.25 per cent.

Brazing and Welding.—Brazing by the usual methods should be quite successful except in the case of type B brass, when considerable care will be necessary when the copper content is at the low end of the range and a high melting point brazing spelter is used. Welding operations conducted on the cast brasses should give little trouble with the oxy-acetylene process, using an oxidising flame and brass filler rods of the Sif-Bronze type. Electric welding is not recommended.

Applications.—Examples of suggested applications for cast brass, types A and B, are given in Table V.

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[4] W. C. Stewart, Amer. Soc. Naval Engineers, 1938, Vol. L, p. 107.

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[6] "Rules for Construction of Unfired Pressure Vessels," Section 8, A.S.M.E. Boiler Construction Code, 1940 edition.

[7] J. Strauss. "Metals and Alloys for Industrial Applications Requiring Extreme Stability." Trans. Amer. Soc. Steel Treating, 1929, Vol. XVI, p. 191.

[8] W. Lines. "Prevention of Dezincification," *Metal Industry* October 31, 1941.

PART III.—THE FOUNDING OF TYPES A and B BRASSES

In the discussions held by the Non-Ferrous Sub-Committee on the War Emergency Specifications for lower tin content gunmetals and cast brasses the general consensus of opinion was that little difficulty would be experienced by the non-ferrous founder in connection with the production of gunmetals to the new specifications. It was, however, felt that some trouble might arise in connection with the production of castings in Cast Brass Types A and B and practical tests were therefore conducted by Mr. E. J. L. Howard and Mr. J. Arnott. The results of these tests and the comments of the two investigators are set out below.

Tests conducted by Mr. E. J. L. Howard

The British Standards Institution has issued War Emergency Specifications Nos. 1025-1028 for cast brasses as shown in the tables on this page.

Experience has shown that the methods of running castings made of these alloys need not differ from those adopted for bronzes unless the copper content of the Type B is on the low limit and the aluminium on the high limit, when the characteristics of the alloys resemble those of manganese bronze. In such cases, moulding methods similar to those adopted for manganese bronze are necessary because of the high shrinkage of the alloy. Care should, however, be taken to avoid running into this difficulty. The metal runs well and gives a good casting surface. The type of sand and mould dressings used for bronzes is quite suitable for the production of sand castings and it has not been found necessary to adopt excessive venting.

It is advisable to pour both types of alloys at a lower temperature than that adopted for bronze. High casting temperatures appear to cause scabbing and poor casting surface.

Some results obtained with test-bars melted under

	Type A.	Type B.
Copper	70 to 80 per cent.	62 to 70 per cent.
Tin	2 per cent. max.	2 per cent. max.
Lead	1 to 4 per cent.	1 to 4 per cent.
Zinc	Remainder ..	Remainder.
Aluminium	0.01 per cent. max.	0.25 per cent. max.
Iron	0.75 per cent. max.	0.75 per cent. max.
Nickel..	1.0 per cent. max.	1.0 per cent. max.
Manganese	—	0.25 per cent. max.
Metals other than those specified ..	0.5 per cent. max.	0.5 per cent. max.

	Separately cast test bar.	Cast-on test bar.	Separately cast test bar.	Cast-on test bar.
Ultimate tensile stress tons per sq. in. ..	11	11	14	14
Elongation per cent. on 2 ins.	20	15	12	10

normal foundry conditions from scrap metal are tabulated. These bars were cast in green sand moulds at a temperature of about 1,000 deg. C. It will be seen that all the bars readily meet the proposed specification for both physical properties and chemical analyses. No foundry should experience any difficulty in obtaining similar results.

TABLE I.—*Results obtained from Scrap Metal Charges*

Cast No.	Cu Per cent.	Sn Per cent.	Pb Per cent.	Zn Per cent.	Fe Per cent.	Ni Per cent.	Al Per cent.
A.1	73.41	0.05	2.50	23.83	0.11	0.10	Nil
A.2	70.69	0.12	3.39	25.42	0.08	Nil	Nil
A.3	74.20	0.55	2.80	23.02	0.09	0.14	Nil
A.4	72.90	0.31	2.90	23.56	0.27	0.06	Nil
B.1	66.21	0.24	3.07	30.35	0.08	Nil	0.05
B.2	63.41	0.61	2.89	32.80	0.18	0.11	Nil
B.3	64.71	0.36	2.12	32.40	0.26	0.10	0.05
B.4	64.11	0.87	2.95	31.96	0.11	Nil	Nil

Physical Tests

Cast No.	Ultimate stress. Tons per sq. in.	Elongation per cent. on 2 ins.	Brinell hardness.
A.1	15.9	32	47
A.2	15.1	30	49
A.3	14.2	21	56
A.4	13.8	24	53
B.1	14.3	41	50
B.2	16.0	27	57
B.3	15.1	32	53
B.4	14.3	16	62

The addition of lead to these alloys makes them particularly easy to machine and enables sleeves and bushes made from them to run together without seizure occurring. Tests have been made to ascertain the effect of running sleeves and bushes of these alloys with water lubrication under a heavy load. For the purpose of the test a sleeve was mounted on a shaft and rotated at 1,500 r.p.m., a stationary loaded bush being located around the sleeve with a diametral clearance of 12 mils between the two. The weight of the bush and its mountings was 91 lbs. and an additional load of 400 lbs. was added, making a total of 491 lbs. Undue wear was indicated by the power to drive fluctuating from relatively low values to

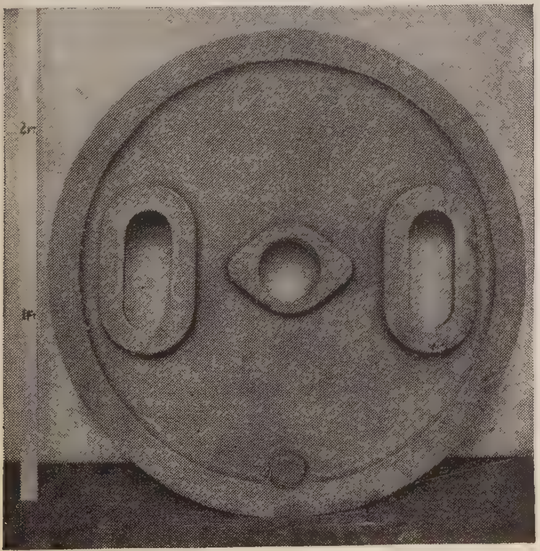

FIG. 1.—AIR-PUMP COVER, TYPE B BRASS.

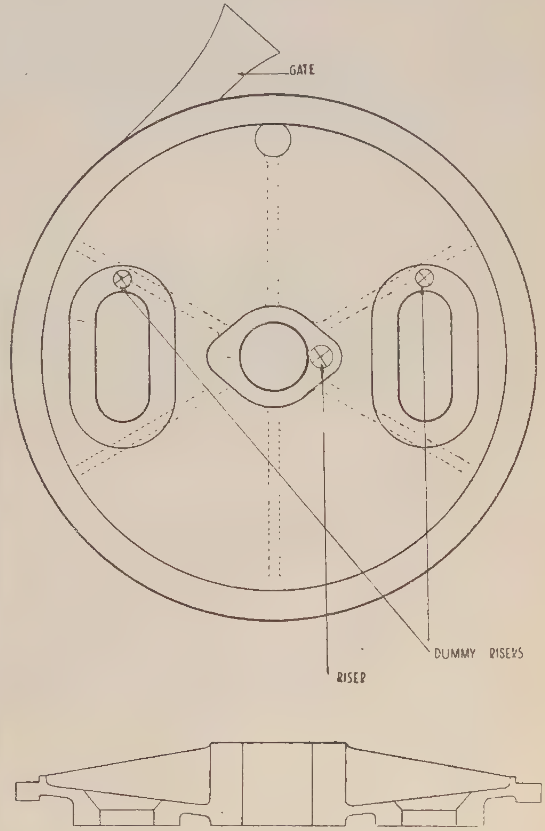

FIG. 2.—SECTION METHOD OF GATING AND FEEDING AIR-PUMP COVER.

high values, measured with an ammeter. In all cases, the brasses ran quite well, and gave no indication of seizing. They also ran well with bronzes which are lead-free. Most bronzes, providing one or both contain 2 per cent. or more lead, will run without seizing under similar conditions of test. Bronzes which do not contain lead seize, as is the case with the brasses.

The addition of tin to the alloys appears to aid the casting properties. The metals appear to run more readily than without tin and have a better finish. Tin adversely affects the ductility of the metal measured by elongation but improves slightly the resistance to corrosion.

Both grades of brass have been used for small valves weighing about 2 lbs., caps to withstand 100 lbs. pressure, brackets, flanges, logging rings, sleeves and bushes, with complete success, and no difficulty has been experienced in the founding of these castings. The methods of moulding were the same as adopted for bronzes.

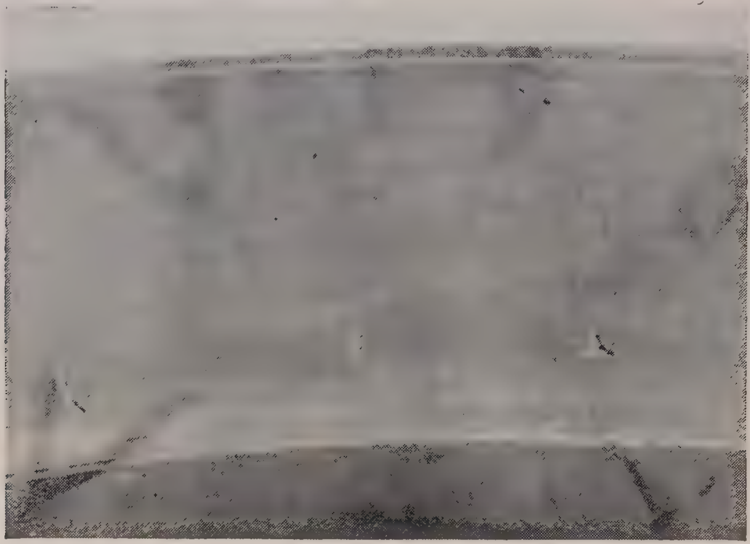

FIG. 3.—OUTER FLANGE OF AIR-PUMP COVER, SLIGHTLY MAGNIFIED, SHOWING SMALL SHRINKAGE TEARS.

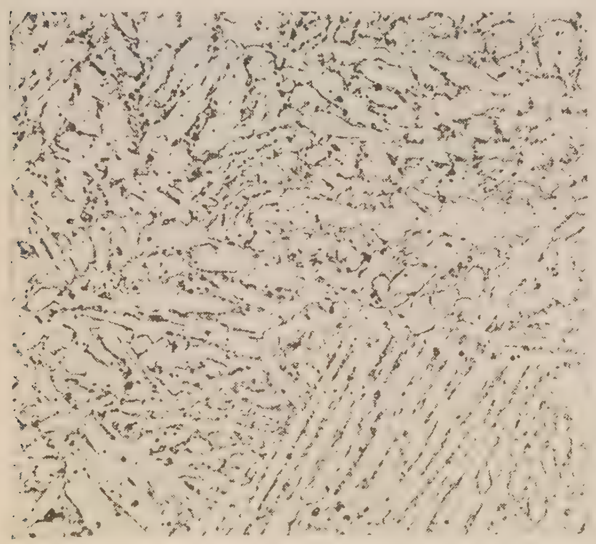

FIG. 4.—TYPE B BRASS: STRUCTURE OF AS-CAST SECTION, × 50, ETCHED WITH AMMONIACAL AMMONIUM PERSULPHATE.

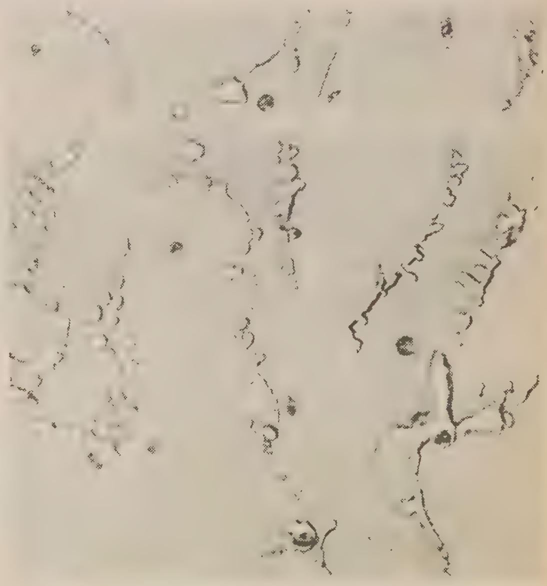

FIG. 5.—TYPE B BRASS: STRUCTURE OF AS-CAST SECTION, × 500, ETCHED WITH AMMONIACAL AMMONIUM PERSULPHATE.

Tests Conducted by Mr. J. Arnott

A test was made to determine if any difficulties would be encountered in making a medium sized casting in Type B brass using moulding and gating methods commonly adopted for gunmetal.

The example chosen was an air pump cover which weighed 2¼ cwts. in the rough. This casting is roughly 30 in. in diameter, and is illustrated in Fig. 1. It was made in dry sand, run from the rim with one main riser on the centre flange boss and two dummy risers on the elliptical flanges as shown in the sketch outlined in Fig. 2. These feeding arrangements were not very generous, but they give satisfactory castings in gunmetal.

The metal used was scrap naval brass rod ends, etc., from the machine shops, and the only addition in melting was a quantity of zinc sufficient to balance that lost during melting. The test was made before the issue of the specification for Emergency British Standard Cast Brass Type B, and the metal employed does not quite meet the requirements with regard to lead content.

The analysis of the casting was as follows:—

Cu	60.46 per cent.
Sn	1.20 „
Pb	0.54 „
Zn	37.53 „
Fe	0.17 „
Ni	Trace
Mn	Nil
Al	0.04 per cent.

The aluminium was estimated by the mercury cathode method, and the figure given may be considered accurate to less than ± 0.01 per cent. (An outline of the method of conducting this test is given as an appendix to these notes.)

The rough casting looked quite satisfactory; there were no signs of shrinkage defects or sinks. When it was machined, however, a number of small shrinkage tears were found in the bore and on the outer flange. These are shown on Fig. 3, taken at twice natural size. It is doubtful if these defects are serious since they are of little depth, but they would be considered objectionable in a high-quality casting. Doubtlessly modified gating and feeding methods would eliminate these imperfections, but it is interesting to note that, in a casting of this size, the differences in characteristics between gunmetal and Type B brass are distinctly noticeable.

A sound section taken from the rim of the casting was examined by the Mond Nickel Company, Limited, for mechanical properties and structure. A tensile test-piece 0.505 in. in diameter with 2 in. gauge length was prepared, and gave the following results:—

Limit of proportionality, tons per sq. in.	4.5
0.1 per cent. proof stress, tons per sq. in.	7.0
Yield point (0.5 per cent. elong. under load), tons per sq. in.	8.8
Ultimate stress, tons per sq. in.	15.0
Elongation per cent. on 2 ins.	9.0
Brinell hardness (10/1,000/15)	90.0

Figs. 4 and 5 illustrate the structure of the section at 50 and 500 magnifications after etching with ammoniacal ammonium persulphate. Fig. 5 is of particular interest, as it shows the distribution of what is apparently the delta constituent arising through the presence of tin. This constituent promotes brittleness, and it is interesting to note that in this case a tin content of 1.2 per cent. has reduced ductility as indicated by elongation to 9.0 per cent. It might, therefore, be assumed that when the copper content in Type B brass is on the low side of the compositional range a tin content of 1.0 per cent. should not be exceeded, otherwise some difficulty may be experienced in meeting specification requirements so far as elongation is concerned.

APPENDIX

MERCURY CATHODE METHOD FOR THE DETERMINATION OF ALUMINIUM IN BRASS OR BRONZE, BY J. MCPHEAT (ASSOCIATE MEMBER).

Weight of Sample.—

5 grms. sample for aluminium less than 0.1 per cent.

2 grms. sample for aluminium from 0.1 to 0.5 per cent.

1 grm. sample for aluminium from 0.5 to 2.0 per cent.

Method.—Dissolve in 25 ml. dilute nitric acid (1:1), boil and separate tin if present in the usual manner. Add 10 ml. sulphuric acid (conc.) and take down to fumes of SO_3. Fume strongly for 3 mins., cool, add 100 ml. distilled water and boil to dissolve salts. Cool, and wash into an electrolysis beaker (Fig. 6) containing 20 ml. mercury and electrolyse overnight (16 hrs.) at 1 amp.

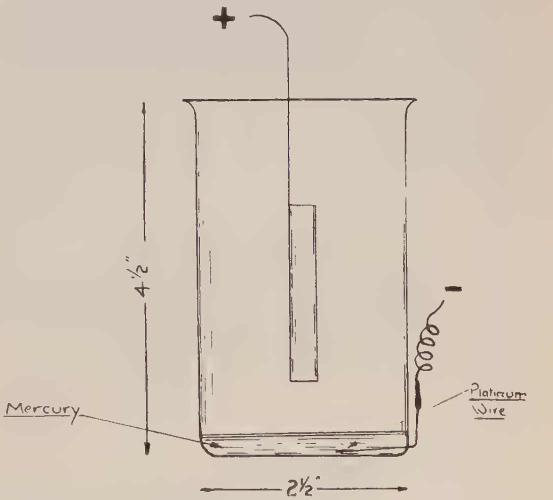

FIG. 6.—ELECTROLYSIS BEAKER FOR THE ESTIMATION OF ALUMINIUM IN BRASS BY THE MERCURY CATHODE METHOD.

When electrolysis is complete, quickly transfer the clear electrolyte to a 600 ml. beaker and wash the mercury and beaker by decantation (10 washes), add 5 grms. ammonium chloride and a few drops of sulphurous acid and boil for 1 min. Cool, add ammonium hydrate till just alkaline to methyl red, boil for 2 mins., settle, filter and wash with 2 per cent. ammonium chloride solution, and finally with hot water.

Ignite and weigh as Al_2O_3, calculate to Al.

Alternative precipitation, for very low percentages and referee work.

After the first precipitation of aluminium, filter and wash as above, dissolve the precipitate in hot hydrochloric acid (1:1), dilute to 100 ml. with water, make just ammoniacal, then acid (3 drops excess acid) with hydrochloric (1:1). Add 3 ml. saturated ammonium bisulphite to reduce any slight trace of iron. Add 3 drops methyl orange, quickly bring to neutrality with ammonium hydrate, then add 3 ml. of (1:1) hydrochloric acid in excess. Add 5 ml. phenyl-hydrazine and stir until the precipitate becomes flaky. The supernatant liquid should be plainly acid to litmus. Settle 15 mins. Filter and wash with phenyl-hydrazine wash solution. Ignite first at a low temperature (600 deg. C.), then at a high temperature (900 deg. C.), and weigh as Al_2O_3.

Notes.—Phenyl-hydrazine solution for washing: Add saturated SO_2 water to a few ml. of phenyl-hydrazine until the crystalline sulphite first formed is redissolved, then add phenyl-hydrazine drop by drop, with vigorous agitation till free from SO_2. Dilute this solution 10 ml. to 100 ml. of hot water for use. For accurate work the Al_2O_3 residue may be treated with HF and H_2SO_4 for the removal of possible SiO_2. In an alloy containing phosphorus, it is advisable to precipitate the aluminium as phosphate.

PRESENTATION OF REPORT

DR. L. B. HUNT, presenting Parts I and III of the Report, dealing respectively with the casting of silicon bronzes and the founding of types A and B brasses, drew attention to the foreword to B.S.S. 1021/28, which outlined the policy to be followed in using the tin bronzes and silicon bronzes. It recommended that the 88/10/2 gunmetal should not be used unless essential, that the 87/9/3/1 alloy should not be used at all, and that wherever possible one of the two grades of cast brass made chiefly from scrap should be employed; it also drew attention to the uses that could be made of the silicon bronzes and aluminium bronze in all cases where manufacturers had experience of their use.

He added that the Non-Ferrous Sub-Committee had worked very closely with the British Standards Institution; five of the members of the Sub-Committee were members of the B.S.I. Committee, which had been responsible for drawing up the Specification.

General Policy Defined

With regard to Part I of the Report, dealing with the silicon bronzes as casting alloys, he said the members of the Sub-Committee had had a very long and wide discussion, without reaching very close agreement. It was felt that the average foundry, working on a mass-production basis, could not change over quickly to the use of the silicon bronzes, for which they might require special foundry practice and technique, and that in general the use of a lower-tin bronze would be much more simple. On the other hand, the Sub-Committee was pressed by the Non-Ferrous Metals Control to do whatever it could to make possible the greater use of alloys with low tin contents, or free from tin. The general opinion was that the members could not, as a Committee, make a general recommendation to use silicon bronzes in place of gunmetals, but that, where foundries could handle those alloys successfully, their use should be encouraged. Therefore, the best course was to publish some guiding lines on foundry practice which would help those who were considering the use of silicon bronzes.

Emphasising the importance of the problem of reducing tin contents, Dr. Hunt said figures had been given by critics who sought to show that the amount of tin used in bronzes nowadays was not very large. But he had it on unimpeachable authority that the amount of tin that was being used, until two months ago, in gunmetals, phosphor bronze, and so on, was advancing very rapidly, and that it had to be reduced drastically.

Finally, he expressed thanks to the Committee members, who had worked very hard on the subject since February, and to others who had joined in the work, particularly Mr. M. C. Oldham and Dr. W. O. Alexander.

Low-Tin Content Gunmetals

MR. FRANK HUDSON, presenting Part II of the Report, dealing with the properties of sand-cast low-tin content gunmetals and brasses, said it had been compiled principally to assist Service Departments, engineers and founders to apply the new Specifications to the products they designed or manufactured. In the beginning of Part II he had included, for convenience, 85/5/5/5 gunmetal and had compared it and the two new ones with the well-known Admiralty gunmetal 88/10/2, in order to give a quick and ready comparison so far as design and other matters were concerned.

The most important feature of Part II was the table of applications (Table V). He had drawn it up tentatively, and he asked for as much discussion as possible on those suggested applications; any suggestions as to additional applications would be extremely useful to those who might require guidance in applying the new materials. In conclusion, he said the original suggestion that he should draw up such a report had come from Mr. C. Coldron-Smith (of the Engineer-in-Chief's Department at the Admiralty), to whom thanks were due, not only for the idea, but also for having interrupted his hard-earned leave in order to be present at the meeting.

DISCUSSION

The CHAIRMAN (Mr. D. H. Wood, Senior Vice-President) said it was obvious that a vast amount of work had been involved in the preparation of the report; the fact, he said, that the members of the Sub-Committee had been able to prepare it, in spite of the fact that their routine work occupied almost the whole of their time, was a great tribute to their keenness. Not only the Institute of British Foundrymen, but the country as a whole, owed a great debt to Dr. Hunt and the other members of his Sub-Committee for their work. The fact that the recommendations they had made had been embodied, in the main, in the new B.S.S. was in itself an acknowledgment of the value of the report.

(At this stage Mr. Wood had to leave the meeting, and at his invitation Mr. V. C. Faulkner (Past-President) presided during the remainder of the session.)

The Viewpoint of the Control

MR. H. J. MILLER (Non-Ferrous Metals Control) was grateful for the opportunity to make a few comments which might prevent the discussion taking a wrong turn. It was always very difficult, he said, for founders and other users of copper-base materials to know what the Control was thinking at any given time; indeed, it was rather difficult for the Control itself to know what course it should follow, for things were changing so very quickly. However, the Tin Section of the Control was definitely perturbed by the quantity of tin that was being consumed in the production of gunmetals and phosphor bronzes. It was now just about the largest single use of tin—bearing in mind that there had been a considerable cut in tinplate. Therefore, the situation was rather serious; of the quantity of tin consumed, about 30 per cent. was going into the tin bronzes and gunmetals. Whereas cuts had been made in other directions, as, for instance, in bearings, there had been no tendency to decrease the amount of tin required for the gunmetals. He had been reproached that it was the duty of the Control to take up with anyone who specified bronzes and gunmetals the question as to whether lower grade material could be employed, or whether an alternative alloy could be substituted, or whether the designers of the castings could reduce sections, and so on. That was a task which was rather beyond the capabilities of the limited staff available at the Non-Ferrous Metals Control, however, and he asked founders who received orders from various bodies and specifying engineers to appeal to them to consider alternative materials, such as the silicon bronzes, etc., which might possibly give even improved service; or, alternatively, to give to the Control their views on any of the individual applications.

The issue of the new specifications by the British Standards Institution was an excellent move; it had introduced two or three specifications for gunmetals containing reduced quantities of tin as compared with the normal, and also the specifications for the cast brasses. They would be followed by British Standard Specifications for silicon bronzes, aluminium bronzes and, maybe, other materials as well. The mere issue of specifications, however, was only the beginning of the task; the greater part of it was to ensure that the specifications were applied correctly in industry. Having made those remarks on the general position, no doubt the Control could count on the active co-operation of all the founders.

Raw Material Questions

With regard to the raw materials which should be used in compounding alloys to those various specifications, he said the 88/10/2 alloy, which in the past had been used always for the better-class products, would be partly replaced by the 88/8/4 alloy. In connection with the making of castings in the latter alloy, the Control would like the foundry industry to refrain from ordering ingots from secondary ingot manufacturers, especially if the founders could make the castings directly by one melt, using virgin metals plus their own process scrap. He made that request because the ingot manufacturing industry was rather overtaxed, and it was definitely wrong, and false economy, that that industry should be inundated with orders for the higher-grade materials, when it could not make them from scrap and had to use virgin metal largely. For the lower-grade leaded gunmetals—the 86/7/5/2 and the 85/5/5/5—the Control asked the founders to use scrap charges, or, alternatively, ingot metals purchased from the secondary ingot manufacturers, who were very clever in the use of mixed scrap to produce the desired compositions.

In the production of the cast brasses, of course, the Control wanted low-grade scrap to be used, either directly or, probably more conveniently in most cases, in the form of secondary ingots.

Commending the report to very careful consideration, Mr. Miller said the Control hoped that there would be a much greater use of such materials as silicon bronzes (which were better in service in many instances than the gunmetals) and of the low-grade brasses, for he felt that those were two directions in which most advance could be made.

Commenting on the statement in Part II of the report, that cast brasses, types A and B, were not recommended for use at elevated temperatures and that there were no published data available of their mechanical properties, he said he did not agree entirely. He believed the statement was taken from the British Standard Specification, with which he had had some connection; but he had overlooked it there, and it had been brought to his attention again by the Report. Certainly he would agree that cast brass, type B, which was an alpha-beta brass, would be poor at elevated temperatures, but he was not certain that that would be so in the case of type A, which would have a wholly alpha structure. It was quite true, as Mr. Hudson had stated, that there were no data concerning creep or other properties at elevated temperatures; but, having looked up the very few figures which had been published on wrought alpha brasses, he said they rather supported his view that, at temperatures up to 200 and 250 deg. C. (of the order of 400 to 500 deg. F.), cast brass, type A, might not be inferior to gunmetal.

Current Trends

MR. G. L. BAILEY (British Non-Ferrous Metals Research Association) said that the main difficulty, or one of the main difficulties, in ensuring the use of the alloys of the lowest tin content possible was that for certain applications the high-grade materials, such as the 88/10/2 alloy, were still required. It would be easier if it were possible to prohibit their use; but, unfortunately, that could not be done, and the high-grade materials had had to stand, with one exception, *i.e.*, the 87/9/3/1 alloy, which was often known as the grade 2 gunmetal of the pre-war specifications. The B.S.I. Committee had felt that there was nothing for which that alloy was used for which a substitute could not be used; therefore, the specification suggested that the 87/9/3/1 alloy should not be used. Of course, that was only a suggestion, for the specifications were only recommendations. It was hoped to replace the 88/10/2 by the 88/8/4 alloy in quite a number of applications, but not all of them. The most important point, in the view of the Committee, from the point of view of saving tin, was the introduction of the entirely new specifications for cast brasses. There was no doubt that many foundrymen very much liked to use the 85/5/5/5 alloy in particular for purposes for which tin-free secondary metal brass was quite good enough. He admitted that the brasses might give the founders a little trouble, particularly if they were accustomed to the use of the 85/5/5/5 alloy; when using the type B brass there was a danger, as had been pointed out by Mr. Hudson, when one came to the lower copper content of that range (62 to 70 per cent.), in that the technique had to be altered; it became very much a manganese bronze technique rather than a gunmetal technique. That was very much in the minds of the Committee. The original suggestion was for a type B brass of 60 to 70 per cent. copper; then there was a reference to an alloy containing 65 per cent. copper, but that was altered by the Committee to a minimum of 62 per cent. However, Mr. Bailey emphasised as strongly as he could that the cast brasses as a whole were the materials which certainly should be used wherever they could be used.

Foundry Propaganda Needed

With regard to Mr. Miller's indication of the attitude of the Non-Ferrous Metals Control on the matter, and of the fact that the Control had not the manpower to be able to consider each individual case on its merits, Mr. Bailey commented that the industry could help to a very great extent by advising customers as to the alloys they should use for their various purposes. It was necessary, however, first to make quite sure that the foundry industry was sufficiently familiar with the characteristics of the alloys; and it was from that point of view that the Report of the

Non-Ferrous Sub-Committee of the Institute had been prepared. He suggested that the foundry industry would be very well advised to experiment with such of the materials as were new to them, so that they would be in a position to deal with them if they were asked to do so. If they got to know and to like one of those alternative materials—he would not call them "substitutes," because some of them were equal to those which they replaced—they should be able to recommend its use to their customers with every confidence.

The Charcoal Enigma

From that point of view he was a little disappointed by the silicon bronze part of the Report (Part I). Dr. Hunt had called attention to the fact that, whereas one maker would say that charcoal must not be used, another would say that charcoal must be used; it might also have been mentioned that, whereas one maker held that there must not be any lead contamination, another implied that it was satisfactory. Mr. Bailey felt that the information given in the Report with regard to the silicon bronzes might with advantage have been extended a little, for it was in some respects contradictory, and it would not be easy for anyone who was a perfect stranger to the material to decide exactly what he was required to do.

Part II of the Report, dealing with the sand-cast low-tin content gunmetals and brasses, contained some extremely useful and interesting data, the collection of which must have been quite difficult, and the industry must be extremely grateful to Mr. Hudson for the trouble taken to collect it. Inevitably, however, there must be small points in respect of which there was not complete agreement. Referring to the behaviour of the brasses in corrosive conditions, he said there was no doubt that, in respect of resistance to the action of sea water, one of the main differences between type A and type B brass was that the β phase present in the type B was very liable to dezincification; and he did not think that at the moment anyone knew how to prevent it. In the type A material, which was an α alloy—he wondered whether it was possible to get a little β in a type A brass—arsenic and possibly antimony and phosphorus would prevent dezincification. He did not much like Mr. Hudson's suggestion that, in order to avoid dezincification in type A brass, there must not be more than 20 per cent. of zinc present. The point was that it must be an α structure.

MR. A. J. MURPHY (Chairman of the B.S.I. Committee on Cast Copper Alloys) said that there was indeed a great treasure of information in the Report, and by the publication of it the Institute was placing it where it could produce the results which were so much desired. It did not leave any important aspect of the matter undiscussed, so far as he could see.

Care Needed to Cast Type B

Leading up to the general point that the Report would give to founders a better appreciation of the qualities of some of the materials dealt with, he said that they must guard against the danger of supposing that some of the things which metallurgists had known in the past as geese had suddenly become rather remarkable swans. Type B brass was not a new invention; the foundry industry had fought shy of making high grade castings with it, not because of prejudice, but as the result of some painful experiences. It was interesting that Mr. Arnott in his experiment of making a medium-sized casting (2¼ cwts.) in type B brass, using moulding and gating methods commonly adopted for gunmetal, had not brought the test to a successful conclusion. Mr. Arnott had observed that, in a casting of that size, the differences in characteristics between gunmetal and type B brass were considerable. The tests illustrated that, if a foundry were producing that particular casting in gunmetal and were required to change to type B brass, production would stop at once—assuming that the casting had to be of reasonably high quality—until the necessary changes of method had been ascertained. In the desire to save tin foundrymen must avoid waste of man-hours due to founders, who were perhaps not very experienced in the use of type B brass, falling into that sort of trouble. In saying that, he did not wish to criticise the work that had been done, but to stress a point which the contributors to the Report had already made.

Expressing appreciation of the remarks of Mr. Miller, and being aware that the Non-Ferrous Metals Control, with the aid of a very small staff, had to perform a giant's task, he asked them to believe that the industry was prepared to go more than half way to meet them. They could take encouragement, for example, from the fact, in connection with tin economy in plain bearings, that the industry had needed little more than a hint from the Control as to the direction in which its collaboration would be welcomed, and it had worked out what had proved to be an extremely successful means of saving tin. He believed the same spirit existed in the yellow metal foundry industry; and if the Control would give a definite lead, and any help and instruction they were able to supply, they need not fear resistance from the industry.

Commenting on the conflict of views concerning the use of charcoal as a cover to the silicon bronze melt, he said the two silicon bronzes dealt with in Part I of the Report differed in certain respects as regards composition, and he would like to hear whether Dr. Alexander thought that those differences would account for the need for charcoal in the one case and its prohibition in the other.

The Charcoal Enigma Solved

DR. W. O. ALEXANDER said the P.M.G. metal was developed essentially as a substitute for gunmetal in the days when tin was very expensive. Everdur, on the other hand, was developed primarily as a corrosion resistant alloy and secondly as an alternative for tin bronzes. It would be noted that all P.M.G. contained zinc, whereas for Everdur a zinc content of from 0 to 1.0 per cent. was specified. The reason why P.M.G. could withstand the use of charcoal as a cover to the melt was that there was a partial vapour pressure from the zinc, and the danger of a gas pick-up was not so great as in Everdur, which might be zinc-free. The makers of P.M.G. always preferred to have a charcoal cover to prevent oxidation, whereas in the case of Everdur some oxidation was tolerated; it was only very slight, because silica sand was quite protective, but it was desired to avoid any chance of absorbing gas from material such as charcoal.

Another point was that, inasmuch as there was no zinc in the original Everdur, there was a tendency towards some slight reaction between the sand of the mould and the metal during the pouring, but the presence of the zinc in P.M.G. inhibited that effect. Whereas zinc could not be tolerated in ordinary Everdur as used for chemical plant, yet in order to help the industry, and assuming there would be a call for silicon bronzes, the makers were prepared to add up to 2 per cent. of zinc. This addition should further assist in the founding and production of sound silicon bronze castings.

Recalling Mr. Bailey's reference to lead, Dr. Alexander said that item also emphasised a difference between P.M.G. and Everdur. P.M.G. contained iron, and always had a second constituent present in the form of iron silicide, and the presence of lead was not favoured. He suspected this may be because a complex iron-lead silicide may be formed; in any case, the presence of lead in P.M.G. would not produce so favourable an improvement in machinability, because although the actual machining might be improved yet the iron silicide particles were hard and tended to cause increased tool wear. By including lead in Everdur which was free from lead particles, the machinability could be improved; with small amounts of lead in Everdur there had been no untoward difficulty in producing sound castings. The reference to lead, in the Report, was included to emphasise that the possibility of mixing gunmetal or leady brass in silicon bronze melts, particularly Everdur, was not so bad as having Everdur mixed in gunmetal melts.

In order to help founders avoid this possibility, it was considered advisable to devise a spot test so that silicon bronze can be readily differentiated from the more normal melts such as gunmetal, brasses, leady brasses, etc.

New Types Favoured by Admiralty

MR. C. COLDRON-SMITH (Admiralty) said it would be ungracious for him to attempt any criticism of the Report, considering the extent to which the Admiralty had used the information contained in it. In the first place, he wished to convey to the members of the Sub-Committee, and to the other gentlemen who had so kindly helped, the thanks of the Engineer-in-Chief on behalf of the Admiralty. Their assistance had been very greatly appreciated, particularly when it was remembered that much past Admiralty experience had been with the 88/10/2 alloy. The Admiralty had been confronted, of course, with considerations of the problems of production and of service; so that it was only too grateful to accept the offer of assistance from the Institute. He hoped that the information contained in the Report would be given very wide publicity, not only among foundrymen, but also among designers; the data which Mr. Hudson had assembled in Part II of the Report particularly should be brought to their immediate notice by all possible means.

Contractors to the Admiralty would be receiving a letter shortly to indicate how the specifications were to be applied. The Admiralty scheme followed very much the lines laid down in Table V (suggested applications of gunmetals and cast brasses) in Part II of the Report, and as outlined in the foreword of B.S.S. 1021/28. The aim was to make the 86/7/5/2 alloy the standard for Admiralty purposes, using the 88/8/4 or the 88/10/2 alloys when the 86/7/5/2 was not obtainable or where Service conditions demanded their use. It was not foreseen that they could make very much use of the 85/5/5/5 material, and it was thought better, for the sake of foundry organisation, to try to restrict the main alloy to the 86/7/5/2 type.

Concluding on a note of warning, Mr. Coldron-Smith said it was found, when the first attempts were made to debase the gunmetals by the use of B.S.S. 900/1 alloy, that certain naive people were actually adding lead to virgin metals. It was hoped that, in the preparation or the use of the 86/7/5/2 alloy, that sort of thing would not occur. Whilst appreciating that probably the temptation was rather great—because he was informed that the alloy was cheaper to make in virgin metal than from scrap—he stressed that, in view of the need for economy, that sort of thing really must come to an end.

Maximum Tensiles Too High?

MR. E. J. L. HOWARD, emphasising some of the points made by Mr. Bailey, said that it was advisable in certain cases not to depart from the use of alloys such as the 88/10/2 or, at least, to use alloys which were lead-free. One particular application he mentioned was the making of slip rings for rotary converters; ½ per cent. of lead in Admiralty gunmetal used in such high-speed machines led to the wearing of the rings in such a way as to reduce considerably the efficiency of the machines.

Commenting on Mr. Murphy's reminder that the type B brass was not new, he said he believed the main objection to such alloys in the foundry had been that the fumes they produced gave rise to unhealthy conditions. However, that objection had been overcome largely by the application of modern means of ventilation.

Apologising for the brief note he had made in the Report with regard to test casts, and the results obtained, Mr. Howard said that if more time had been available the work put in would have been of more value; the castings made were of only 5 to 6 lbs. weight, and he appreciated that in attempting to make larger castings, such as that made by Mr. Arnott, trouble might have been experienced, particularly where the copper content was low. Where such trouble occurred he would take strong measures immediately and would increase the copper content to about 66 per cent., for there was danger in getting down to the β structure.

Although the minimum tensile figure he had given was about 14 tons per sq. in., he felt that the specification of 14 tons was rather on the high side, and that to stipulate 12 tons for the α type and 14 tons for the β type was not altogether right. It would have been better to have stipulated 11 tons per sq. in. for both brasses. This would give a fair margin in the foundry.

When to Use Charcoal

MR. R. F. HUDSON, referring to the silicon bronzes, said that for Everdur he always used an oxidising atmosphere, for difficulty had been experienced when using a reducing atmosphere. Commenting on the use of charcoal as a cover for P.M.G., he said that if an oxidising atmosphere were used it might be satisfactory, but with a reducing atmosphere, when using charcoal, trouble would possibly arise. Referring again to Everdur, he said that if he had a reducing atmosphere in the furnace he would use an oxidising slag.

Referring to chills, he said that he had cast a large quantity, mainly in phosphor bronze, but also in gunmetal and Everdur, and had found that solid bars in Everdur and gunmetal had a definite tendency to porosity, owing to the short freezing range. Only when the best technique was employed was he able to obtain good castings, and even then some porosity could still be seen by the aid of the microscope.

Commenting on Dr. Alexander's tests, he asked what shape of test-bar he had used for Everdur, and whether he had tried the U.S. Navy bar, made with two small ingates and the heavy riser above.

Dealing with the experiments on the new brasses, in which castings weighing up to 4 and 5 cwts. had been made, he said the first of those castings were made free of aluminium. The second, which contained 0.1 per cent. aluminium, was a very bad casting, the shrinkage being much greater than when there was no aluminium present. The castings made with Everdur were very good, giving no trouble at all.

With regard to Table V, a suggested application for the 86/7/5/2 alloy was the making of slip rings for electrical equipment. He wondered whether 96 per cent. copper and 4 per cent. nickel would prove to be a more suitable alloy for that purpose.

The Case for Low Tin Bronzes

MR. F. DUNLEAVY was pleased that the trend of the discussion so far appeared to be to support the lower-tin-content gunmetals against the silicon bronzes. Emphasising the difficulties which would be experienced by what he called the "backyard or back-street foundryman" if a change were made at once to the use of the silicon bronzes, he said their numbers were legion and they were making pressure castings for the Admiralty; how, he asked, could they be expected to make those castings in a new material without experiencing considerable difficulty? The far better course was to make those castings in the low-tin bronzes similar to the types already in use, and to make them sound, rather than to make them in silicon bronze and then to re-make them before they could be regarded as satisfactory. At a recent meeting in Manchester the problem of the contamination of silicon bronze by tin and tin bronzes was discussed. The suggestion was made that there should be a separate foundry for each class of material; but surely that was not possible. There must be something reasonable; and, in supporting the suggestions of the Non-Ferrous Sub-Committee, he felt sure that foundrymen were at last getting down to real business. The average foundryman, he said, would make castings in silicon bronzes, P.M.G. or any other material, provided he had some assistance from the metallurgical side; if he had not that assistance, he would not be successful. He must know the material he is using, and also the control of the composition, back scrap and machine-shop return. There were more of the "backyard" foundries than of others, and it was necessary to consider them; otherwise, they would be pushed out of business, and the country would lose the benefit of the experience of many men who were doing a satisfactory job, contributing to the war effort.

After complimenting Mr. Hudson on a very fine effort, Mr. Dunleavy asked for the feeling of the meeting with regard to the lower-tin bronzes versus the silicon-bronzes; he would like to know the views and experiences of others in connection with the use of those materials.

Reaching the Designer

MR. A. LOGAN did not think it was necessary for him at that stage to offer any criticisms on the technical aspects of the Report; but he welcomed it as a very excellent piece of work, which provided excellent guidance for the practical foundryman. A consideration which rather worried him, however, was that, whereas at the present stage the Report would be circulated to foundrymen, who were, one might say, already converted, it ought to be distributed also to those who were concerned with design and specification. It was admitted, he said, that foundrymen were anxious and willing to play their part by utilising the low-tin bronzes as far as possible, and thus assist in the conservation of tin. In very few cases, however, had the foundrymen any say on matters of design and specification. It was necessary that the test results and the recommendations published in the Report should be brought to the attention of those who specified the materials of which castings were to be made; and in the majority of cases that started in the design room or drawing office. It was quite possible that, if the information given and the recommendations made in the Report were merely allowed to filter through, much valuable time might be lost and much tin would be used which otherwise might be saved. In order to direct attention to the Report, he suggested that an official letter from the Admiralty might be sent to the firms who were doing Admiralty work. There were, however, also many firms who were not doing Admiralty work and who might continue to use the high-tin alloys, whereas they would not do so if their attention were directed to the matter in a specific way quickly. He could not suggest exactly what should be done in respect of those firms, but he emphasised that some action needed to be taken, and taken quickly.

A Case in Point

MR. G. HYSLOP supported Mr. Logan's plea that something definite should be done to draw the Report to the attention of those who authorised and specified the alloys that were used; he pointed out that the jobbing foundry, for instance, had little or no control over the alloys specified by the customers. In that connection he mentioned a recent case in which an order was given for 12 tons of ingots in drawn phosphor-bronze mixture, for making castings. He had got into touch with the firm which had given the order; and had suggested that they should get into touch with the Government department concerned with a view to its specifying an alternative mixture. Instead of doing that, however, they had referred the matter back to the Control, who did not know the exact purpose for which the mixture was to be used. Ultimately the matter was referred back to the customer, and authority was given to use manganese bronze—which was evidence that the castings could be made "in any darned thing at all." Thus, if only one could get at the designers and those who specified and who knew the facts—as, for instance, Mr. Coldron-Smith, who had been concerned with the tests as a representative of the Admiralty and who had had the benefit of the discussions throughout the work described in the Report—the industry should get results. However, Mr. Coldron-Smith represented only one section of the Admiralty, and others might not necessarily follow.

MR. COLDRON-SMITH said the other departments were following the example of his department.

MR. HYSLOP replied that he was glad to hear that; and he wished the War Office and the tank people would follow on the same lines. He had heard that something was to be done to get the designers together. Whilst acknowledging that the Non-Ferrous Metals Control had been extremely helpful, he said he believed Mr. Miller would be the first to admit that the Control relied largely on the honesty of foundrymen. They had not been let down by the foundrymen; but, on the other hand, he suggested that they were looking rather too much to the trade for guidance. They had asked that they should be informed of instances in which metal had been misapplied, so that they could take the necessary steps; but it was not possible to get inside all the foundries and to know exactly the uses to which the various materials were put.

AUTHORS' REPLIES

Part II of Report

MR. FRANK HUDSON, replying to the discussion on Part II of the Report, first expressed gratitude to Mr. Miller for having drawn attention to the facts relative to the mechanical properties of the types A and B brasses at elevated temperatures. He had had a considerable hunt, he said, for data on the subject, but could not find them, and he urged that there was room for quite useful work to assist the application of the specifications by assessing the properties of the two brasses at elevated temperatures. That work might very usefully be considered either by the Non-Ferrous Sub-Committee of the Institute, or alternatively by the British Non-Ferrous Metals Research Association. It would be very useful work and would not occupy very much time. He was glad the matter had been raised, because he was anxious to collect as much data as he could, and he had looked to the meeting to provide the missing pieces.

In reply to Mr. Bailey, he agreed fully, in regard to his remarks on the corrosion resistance of the brasses, that a statement emphasising the alpha structure was to be preferred to a definite assertion limiting the amount of zinc to 20 per cent., for that, rather than the zinc content, was the controlling factor.

Dealing with Mr. Murphy's comments on Mr. Arnott's experiment in making a casting in type B brass, Mr. Hudson said he had seen that casting and had discussed it with Mr. Arnott, who no doubt would say that it would probably have been accepted by the inspection authorities; the defects were not really bad enough to warrant scrapping it. But the inference to be gained from the test was that the normal gating methods employed when using gunmetal—and that particular casting was normally made in gunmetal—did not apply when it was made in type B brass; it was necessary to thicken up the ingates and risers and tend towards the manganese bronze type of technique in order to ensure that the casting would be entirely free from defects.

It was very interesting to hear Mr. Coldron-Smith's remarks on the action which the Admiralty were taking in connection with the use of the emergency alloys. He was, however, a little perturbed to learn that they were standardising on the 86/7/5/2 alloy, particularly if that statement applied to all the Admiralty Departments. For the Engineer-in-Chief's Department that alloy would be extremely useful; but for the Department of Naval Construction, for instance, one could think of castings which were used in large quantities—as, for instance, port-hole lights, of which very many must be needed for a big ship or even a small ship—and for which cast brass could be used. He hoped, therefore, that not all the Departments of the Admiralty were standardising on the 86/7/5/2 alloy; there was a very big field for the application of the cast brasses in the Admiralty, and he would like Mr. Coldron-Smith's assurance that he was not labouring under a misapprehension.

As to the use of the 88/10/2 gunmetal for rotary converter slip rings, no doubt Mr. Howard's statement was correct so far as rotary converters were concerned. But, said Mr. Hudson, in the course of some recent inquiries he had made in order to find out what were the best materials to use for certain purposes, he had approached the Morgan Crucible Company, who made large quantities of carbon brushes for electrical equipment (and the wear of brushes was closely associated with the type of alloy used in the slip ring), and they had assured him that for 90 per cent. of the slip rings required for motors in the electrical industry, the 86/7/5/2 alloy was entirely satisfactory. Indeed, they had gone so far as to state that one of the biggest electrical manufacturers in the country had standardised on that alloy for all the standard types of motors they produced. Therefore, he felt that, whilst the use of the 88/10/2 alloy might be necessary for rotary converters, it was by no means necessary for the majority of the slip rings used in the electrical industry.

That statement, he concluded, partly answered the question put by his brother, because the 86/7/5/2 alloy was more economical than the 96 per cent. copper, 4 per cent. nickel alloy, for the problem of the supply of nickel was also difficult, and the authorities were not anxious to recommend the use of that type of material for slip rings unless required for some special application in which the more common alloys could not be employed.

Parts I and III of Report

DR. HUNT, who welcomed Mr. Miller's remarks as a representative of the Non-Ferrous Metals Control, and acknowledged that he had played a part in the preparation of the Report, said the sense of the meeting was that the Control was assured of the co-operation of the non-ferrous foundries. Dr. Hunt underlined the advice that the foundries should experiment with the cast brasses, looking towards their substitution for the bronzes.

After commenting that the two apparent contradictions, concerning charcoal and lead, in the part of the Report dealing with the silicon bronzes had been reconciled by Dr. Alexander, he recalled Mr. Murphy's emphasis on the reasons why the well-known cast brasses had not been used in the foundries to a greater extent than in fact they had. The Sub-Committee did not wish to suggest in the Report, of course, that those cast brasses should be used by and large, and the warning given by Mr. Murphy was quite timely and worthy of consideration.

With regard to the point raised by Mr. Howard, that the tensile results obtained with the type B brass were only just above the figure of 14 tons per sq. in., and that the figure of 14 tons per sq. in. might be too high a figure to specify, he supposed the Non-Ferrous Sub-Committee could only refer the matter to the British Standards Institution for consideration and for such action as was necessary.

The important point raised by Mr. Dunleavy, that the smaller, less well controlled or uncontrolled foundry, trying to use silicon bronzes after having been accustomed to gunmetals, would run into trouble, had cropped up at the first meeting of the Non-Ferrous Sub-Committee. It was for that reason that the Committee had avoided any general recommendation to employ silicon bronzes in substitution for gunmetals in the general run of non-ferrous foundries. It was mentioned in the Foreword of B.S.S. 1021/28; and in the second paragraph of Part I of the Report it was stated that "although the silicon bronzes are capable of giving reliable castings of good mechanical properties, it is felt that difficulties might be experienced in foundries having no previous experience of these alloys." The aim of the Sub-Committee was merely to give some indication of the facts or some guidance to those firms who might consider themselves sufficiently well set up to be able to supply castings in the silicon bronzes. The same sense was contained in the foreword to B.S.S. 1021/28, where it was stated that "These alloys may with advantage be employed for special purposes if made by manufacturers having experience of such alloys." That being the view of the Sub-Committee on the matter, he was glad to hear Mr. Dunleavy's comments.

In reply to Mr. Logan and Mr. Hyslop, he said the Sub-Committee also were well aware that, in addressing foundrymen, they were talking to the converted, and that it was necessary to consider some means of bringing home the facts to Government Departments (apart from the Admiralty), and to all users who specified cast copper base alloys. Something would be done through the appropriate technical Press; it had not yet been done because the Report had been in print for only a few hours.

Finally, Dr. Hunt thanked the meeting for a very pleasing and interesting discussion of the Report.

Vote of Thanks

The CHAIRMAN (Mr. V. C. Faulkner) proposed a hearty vote of thanks to Dr. Hunt, Mr. Hudson, and all the members of the Non-Ferrous Sub-Committee and those who had assisted them, for having done such excellent work for the benefit of the industry and in the interests of the war effort.

The vote of thanks was carried with acclamation, and the session closed.

PAPERS PRESENTED TO BRANCHES

East Midlands Branch **Paper No. 754**

Pattern Equipment for Quantity Production of Small and Medium Castings*

By F. G. BUTTERS (Member)

Introduction

Although much definite progress has been made in the improvement of pattern layout and mounting in recent years, especially by foundries specialising in castings for the motor, electrical, agricultural, and other industries, from the literary standpoint the subject does not appear to have been given the attention it merits, judging by the scarcity of available data dealing exclusively with this highly important phase of modern foundry practice. In the light of this knowledge the object of the Paper is not to introduce any one particular type of pattern equipment, but is an endeavour to survey briefly some of the more popular production methods, the choice of which is governed largely by one or more of the following factors:—(1) Type of moulding machines available; (2) type of pattern equipment, and (3) quantities required and speed of production.

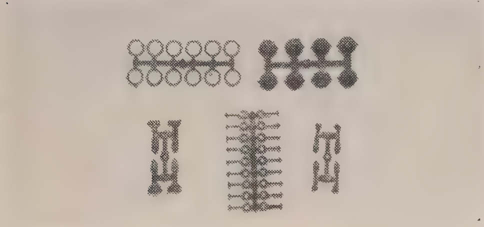

FIG. 1.—SPRAY PATTERNS IN BRASS AND WHITE METAL.

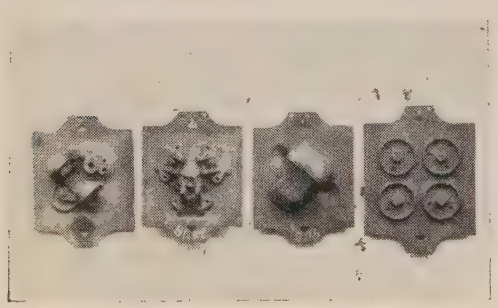

FIG. 2.—SMALL DOUBLE-SIDED ALUMINIUM PATTERN PLATES.

However, before proceeding into technical details, a brief survey of the steady development of present day production methods from those that prevailed in the latter years of the nineteenth century may be appreciated by foundrymen less familiar with quantity production.

Rolling Over Boards

In the first place, it is fairly obvious that the elimination of jointing was the primary object of the moulder, which, it can be safely assumed, was solved on patterns of simple design, namely by ramming a flatback pattern on a board. No doubt this was soon followed by boards having recesses or holes which would allow projections of patterns to lie in or go through completely, as in the case of the boss of a wheel or other similar projections.

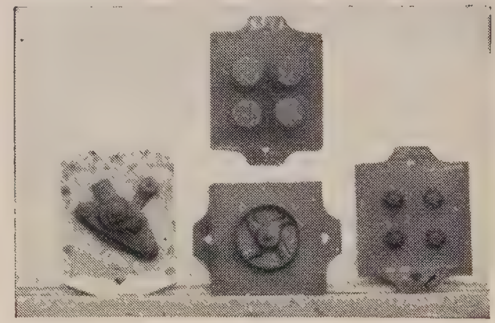

FIG. 3.—PATTERNS MOUNTED ON MACHINED PLATES.

Oddside Moulding

With patterns of irregular contour, the moulder was resourceful enough to observe and appreciate the advantage of an oddside impression, which would in all probability comprise an odd top-part moulding box rammed up with a mixture of sand possessing a good dry bond, so as to permit a reasonable number of moulds to be made from it, the useful life of such an oddside being governed in the first place by the material from which it was made, and secondly by the manner it was treated in service.

Oddside Composition

Sand, however, as a medium for the construction of permanent oddside impressions had serious limitations, due mainly to its friable nature and especially when being subjected to repeated exposure, together with the consequent wear and tear of normal moulding practice.

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* The Author was awarded a Diploma for this Paper.

Efforts to overcome this weakness resulted in the introduction of several mixtures and compounds each more or less successful. Some of the earlier compounds still contained sand as the base material, with additions of vegetable oil, cement, etc., and other binding agents which when dried or baked gave a good hard matrix.

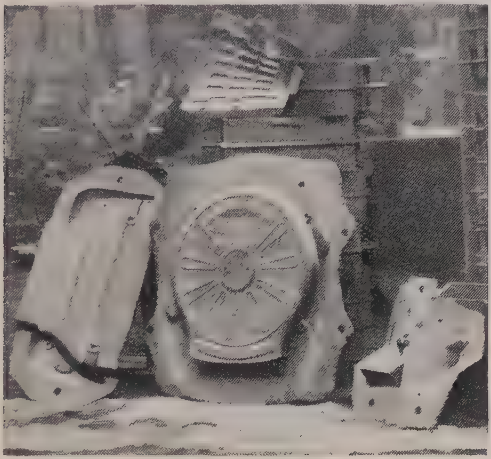

Fig. 4.—Pattern Plates with Irregular Joint Contour.

Development in the improvement of oddside and pattern compounds was still the object of further research and experiment, and no doubt was in a large measure responsible for the introduction of plaster of paris and the compound of plaster and cement for this purpose, which incidentally is still used by many foundries at the present time. Certain advantages over this original material have been claimed in recent years by various proprietary brands of pattern compounds. These include such features as smooth surface finish, the ability to reproduce clearly defined contours and impressions, and less liability to develop surface defects or perish after prolonged use.

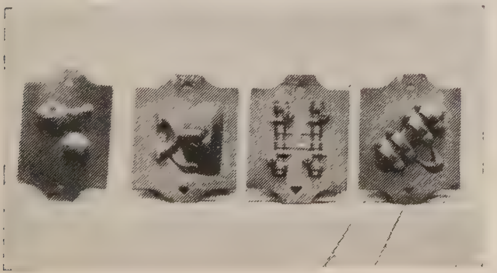

Fig. 4a.—Small Double-Sided Cast-Iron Pattern Plates.

Use of Compounds for Patterns

Although these proprietary materials are used to some extent for oddside impressions, they have a much wider application in the construction of actual pattern plates. This is usually in the form of one half impression in compound, the opposite half being a combination of a metal half-pattern embedded in compound.

In some cases, however, both top and bottom pattern impressions are composed of compound, whilst in others a metal half pattern is embedded in each half impression. Such methods of pattern mounting can be successfully adopted where hand ramming or squeezer type moulding machines are employed, but for use on jolt or jolt-squeeze moulding machines they compare unfavourably with pattern plates of all metal construction, mainly from the standpoint of the lack of physical strength to withstand the severe service conditions imposed on them.

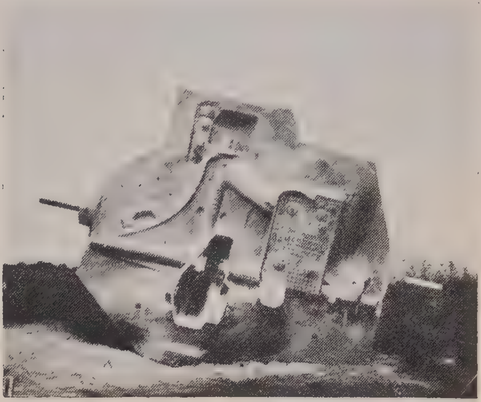

Fig. 5.—Large Pattern Plate of Mower Frame, Approx. Size 5 ft. sq.

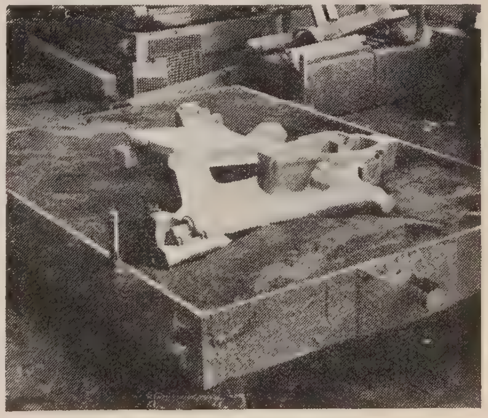

Fig. 6.—Wood Master-Pattern of Mower Frame, in position, prior to Ramming of Drag.

Wood Patterns

Wood patterns have much to commend them, as they can be mounted on wooden boards or metal plates, and can be built up in pine or mahogany, especially the latter, to meet all normal requirements of hand or machine moulding, and can be used successfully on any type of machine. Their choice, however, is governed to some extent by design and the quantity required to be made from them. Economy in weight combined with speed in mounting for production are two distinct advantages of this type of pattern equipment, the former applying of course when manual effort is employed to withdraw same from mould, as in the case of small hand- or pneumatic-squeeze type of moulding. Whilst the advantages of the latter are economy in cost of mounting, together with the saving of time taken to prepare same for production, this being an important factor when speed of delivery of castings is of first consideration.

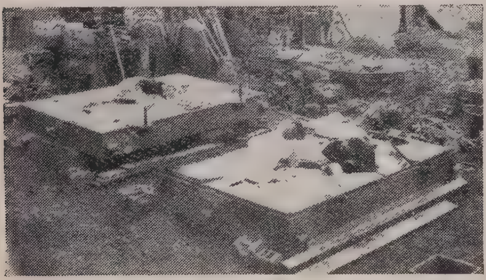

FIG. 7.—COPE AND DRAG MOULDS FOR MOWER-FRAME PATTERN PLATE, WITH PLATE THICKNESS PARTLY BUILT UP ON JOINT FACE (SEEN IN FOREGROUND).

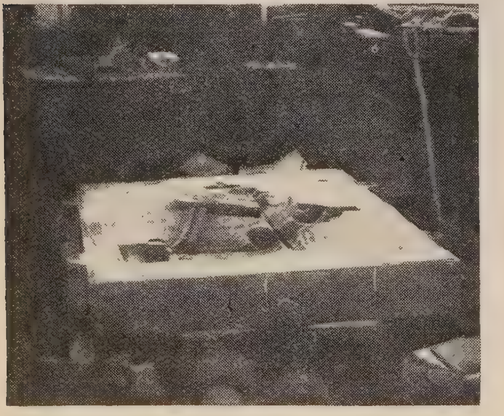

FIG. 8.—TOP HALF MOULD FOR MOWER-FRAME PATTERN PLATE.

In certain instances, therefore, wood has definite points in its favour when compared with metal, but its natural disadvantages prove it to be generally unsuitable for the construction of intricate pattern mountings where precision and accuracy of detail are to be maintained during long spells of service.

Warping is a characteristic disadvantage common to this material, and is aggravated more or less by constant contact with damp sand. Repeated long exposure to strong sunlight may even be detrimental to patterns of a more fragile nature, whilst its inability to withstand the continuous abrasive action of sand serves to some extent to explain the reason for its rejection in favour of metal for mounting of the majority of patterns for repetition production.

In passing, however, to avoid these remarks being misconstrued, the author would like to explain that it is not intended to discourage or even unduly criticise the practice of mounting wooden patterns, but rather to stress some of the inherent weaknesses encountered, all of which contribute to the limitations of such patterns when severe foundry conditions are fairly considered.

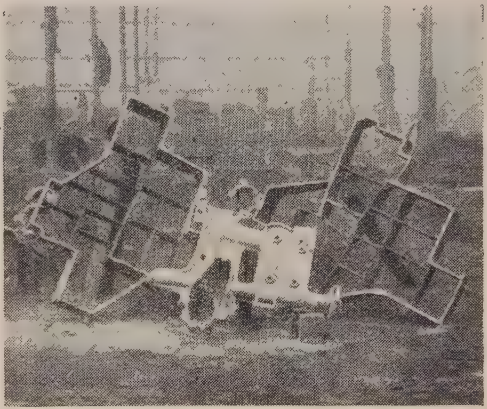

FIG. 9.—PAIR OF MOULDING BOXES AND CASTING OF MOWER FRAME.

Metals for Pattern Construction

The variety of metals used in pattern construction cover a fairly wide range, including cast iron, brass, white metal, aluminium, etc., each possessing qualities peculiar to their respective character or nature, and which usually determine their selection for the many and varied types of pattern equipment.

Cast Iron

Of the above-mentioned metals, cast iron is the one more generally used, and does with few exceptions possess all the more important qualities necessary for the construction of pattern equipment. Apart from it being the most common of metals, its popularity is further enhanced by its simple manner of working, an advantage not generally shared by the alternative non-ferrous metals. From the standpoint of strength, it compares favourably with other metals, and is capable of taking a fine surface finish. It is also more resistant to the abrasive action of sand, a distinct asset where the continuous production of castings with clean edges is necessary.

Brass

The use of this metal in pattern equipment is largely confined to the actual pattern or section of pattern, the same invariably being mounted on plates of either wood, cast iron, aluminium or steel.

It is also extensively used for the construction of spray patterns, such as are seen in Fig. 1. Its popularity for this class of pattern equipment is no doubt influenced to some extent by the ease of construction by soldering, but, as will be observed, the size and section of most of these examples are beyond the practical limits of ferrous metals. Its ability to take a fine surface finish excels that of cast iron, whilst its immunity to attack from rust and resistance to effects of chill are advantages not possessed by cast iron. These features prove it to be ideal for the construction of patterns of exceptional light section, whereas in cast iron such patterns would be unmachinable or very difficult to finish by filing.

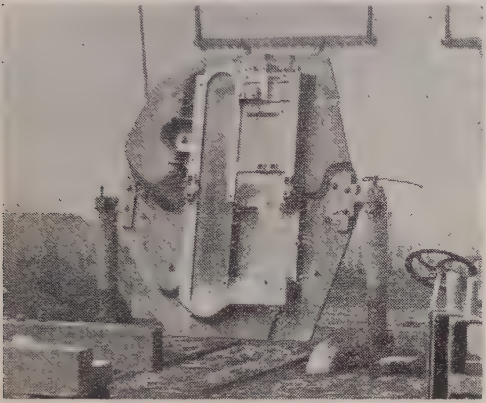

FIG. 10.—LARGE EXAMPLE OF DOUBLE-SIDED PATTERN PLATE, APPROX. SIZE 5 FT. SQ.

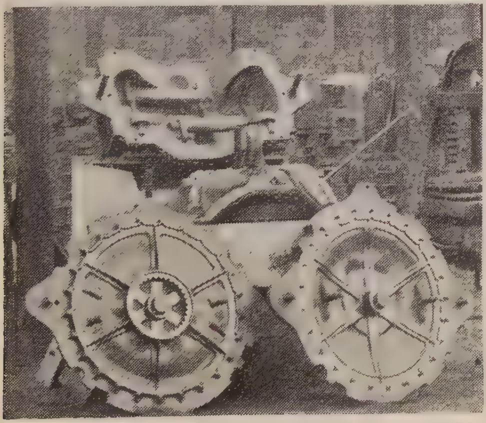

FIG. 11.—PATTERNS PRODUCED BY SPLIT MOULD PROCESS.

White Metal

Although this metal is not so widely used for the construction of actual patterns as either cast iron or brass, due probably to its softer nature, and consequent less resistance to abrasive wear, it is invaluable for the lining of intricate stripping plates, this latter application being the means of effecting an appreciable saving in time and labour in pattern mounting.

Two of the main characteristics having a great influence on its selection for this class of work are its low melting point, which is approximately 260 deg. C., and its immunity from the effects of chill, both factors which enable it to be successfully poured into an unlimited variety of intricate shapes and contours. The substitution of lead as an alternative is not generally recommended, owing to its exceptionally soft nature; it can, however, be added to white metal in small proportions to increase its ductility.

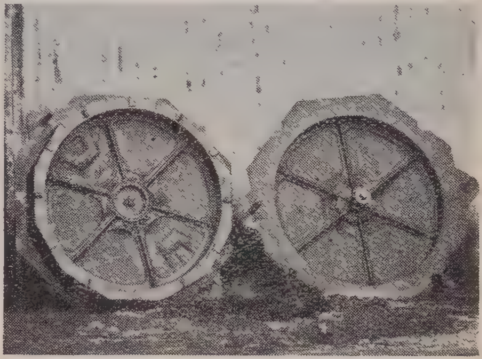

FIG. 12.—PAIR OF PATTERNS FOR TRACTOR WHEELS MADE BY SPLIT MOULD PROCESS.

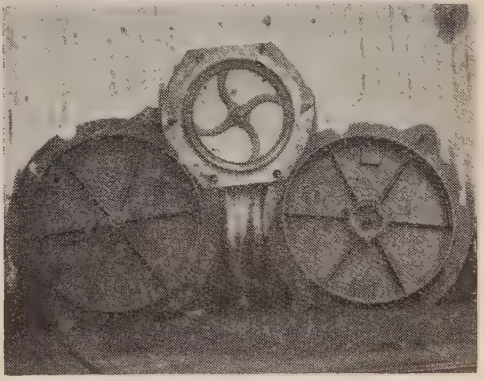

FIG. 13.—GROUP OF CAST-IRON WHEEL PATTERNS MOUNTED ON MACHINED BASE PLATES.

Aluminium

Owing to its exceptional lightness this metal has a wide field of application, especially where the fatigue of constant manual effort is taken into consideration, and, like cast iron, can be used exclusively for almost any type of pattern equipment, including flat plates to be machined for mounting purposes; single-sided plates for hand or machine; double-sided plates for hand or machine moulding; or loose patterns for hand moulding. Although, as explained above, the major advantages of this metal are its low ratio of weight to volume, it also shares the advantages of other non-ferrous metals regarding immunity from the effects of rust and chill, and is reasonably resistant to the abrasive action of sand.

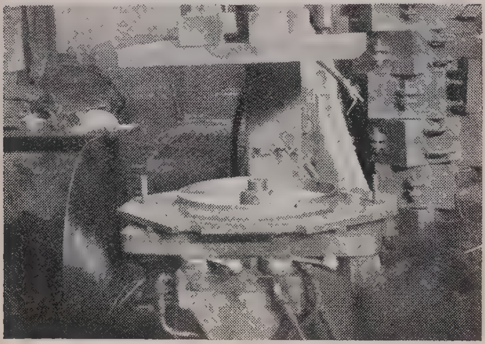

FIG. 13a.—METAL PATTERN MOUNTED ON MACHINED BASE PLATE, FOR THE PRODUCTION OF BOTH COPE AND DRAG MOULDS.

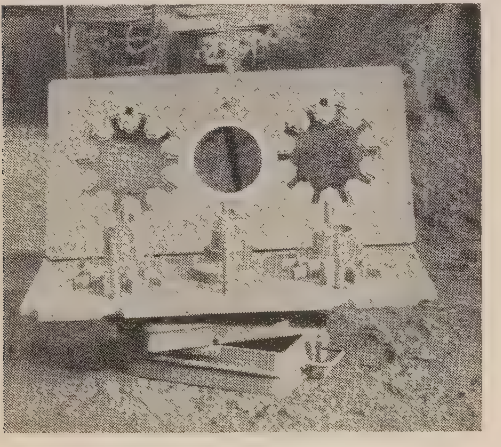

FIG. 13b.—SET OF THREE PATTERN SECTIONS MOUNTED ON BASE PLATE, FOR THE PRODUCTION OF WHEEL HUBS.

Precautions in the working of this metal are necessary to combat the danger of pronounced liquid shrinkage in heavy sections; this in some cases involves a drastic change in the technique of running and feeding, and in some instances necessitates the application of chills or denseners. The pouring temperature should also be carefully controlled, 700 deg. C. being reasonable for small patterns, such as are illustrated in Fig. 2.

Types of Pattern Plates

Pattern plates illustrated in Fig. 3 represent mounting in its simplest form, namely, the split pattern or flatback being mounted on one or either side of the plate, whilst the group shown in Figs. 4 and 4a are complete double-sided plates in cast iron. As will be observed, the pattern plates in Fig. 4 have joint contours of irregular shape which extend to the outer edges of the plates, and consequently involve the use of special moulding boxes. Obviously, this type of pattern plate has a limited field of application in most foundries; nevertheless, it is a type extensively adopted by stove and grate and agricultural foundries.

An explanation of its popularity for this class of work is due in some measure to the complexity of designs which is encountered, especially in agricultural foundries, which, if moulded in boxes having straight joint faces, would not only involve the use of a great deal more sand, but would also mean lifting deep cods, both being serious factors when making repetition light castings.

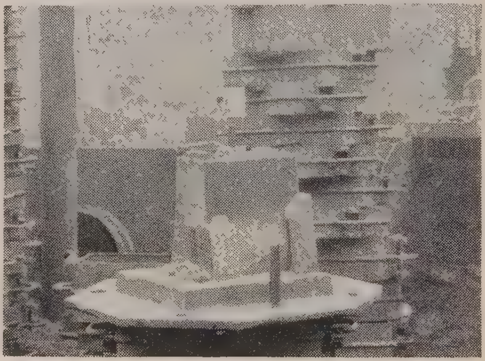

FIG. 13c.—CYLINDER PATTERN OF SMALL PETROL ENGINE MOUNTED ON BASE PLATE.

Regarding the size of such pattern plates the useful limit consistent with safety is a rather debatable point, as, obviously, strength cannot be increased by suitable ribs as in the case of a single-sided plate, but can only be attained by increasing thickness.

The following sections can be safely recommended for cast-iron pattern plates of various sizes:—

Area	10 in. by 10 in.	..	Thickness	$\frac{1}{4}$ in.
,,	14 in. by 14 in.	..	,,	$\frac{3}{8}$ in.
,,	18 in. by 18 in.	..	,,	$\frac{1}{2}$ in.
,,	30 in. by 30 in.	..	,,	$\frac{5}{8}$ in.
,,	36 in. by 36 in.	..	,,	$\frac{3}{4}$ in.
,,	48 in. by 48 in.	..	,,	$\frac{7}{8}$ in.
,,	60 in. by 60 in.	..	,,	1 in.

A pattern of the last size is illustrated in Fig. 5 and, incidentally, this plate is the largest the author had experienced making. Various stages of the moulding of this plate are shown in Figs. 6, 7, 8, and 9. Fig. 10 is also another large example of the 5-ft. square size.

Single-Sided Plates

The adoption of this type of pattern is to some extent influenced by one or both of two principal factors; assuming, of course, that they are to be worked on some type of moulding machine. In the first place, if the moulding equipment is of the pin-lift type, one side of the plate must of necessity be flat and preferably machined. Secondly, if maximum production of moulds is of primary importance machines may be worked in pairs, one producing the cope, the other producing the drag.

Patterns of this type can be produced by two methods, one by casting a complete pair of plates by the split mould process and the other by mounting patterns or sections of patterns on a machined base-plate. The advantage of the latter method is obviously that of dimensional accuracy, which in many cases is essential where castings must be produced to fine tolerance. It is, however, an expensive method and one which in many cases must rely on big quantity requirements to justify its adoption.

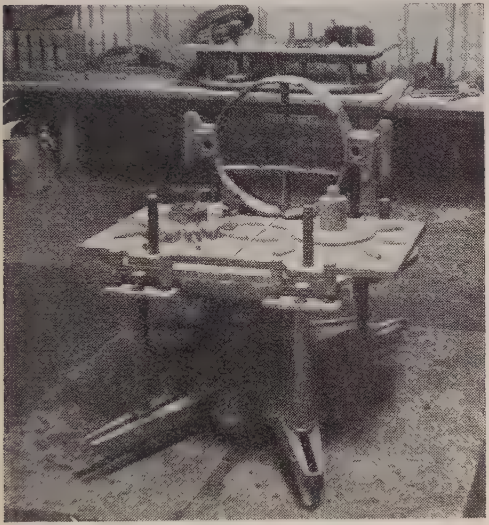

FIG. 13d.—PATTERN LAYOUT FOR PRODUCING COPE AND DRAG MOULDS IN ONE CYCLE OF OPERATIONS, WITHOUT THE USE OF STRIPPING PLATE. ON PIN-LIFT MACHINE.

Split Mould Process

This method of pattern plate production is both quicker and less costly and is capable of giving exceptionally good results, subject, of course, to the exercise of extreme care on the part of the moulder. Briefly, the principles of both methods are similar in character, the difference being the substitution of highly skilled craftsmen in moulding for that of the skilled metal pattern fitter.

A group of plates produced by the split mould process is shown in Figs. 11 to 13c. Fig. 12 is an example of the larger types, measuring 42 in. sq., whereas the group in Fig. 13 is mounted in sections on machined base plates, and include such examples as Figs. 13a, 13b, 13c.

Stripping Plates

The use of the stripping plate is not a necessity in every case where it is employed, but it does, without question, simplify the operation of moulding in every instance. Its use is at times almost indispensable where moulding machines are exclusively of the pin-lift type, especially where the patterns are of intricate design. An exception to this rule, however, is illustrated in Fig. 13d.

It is also an important feature in pattern equipment where two or more moulds are rammed simultaneously on pin-lift machines, such as those illustrated in Fig. 14, but could successfully be dispensed with by the introduction of turn-over moulding machines as shown in Fig. 14a. Such, however, is not the case when considering the production of various types of gear wheels, including straight, helical and spiral toothed gears similar to those illustrated in Fig. 15.

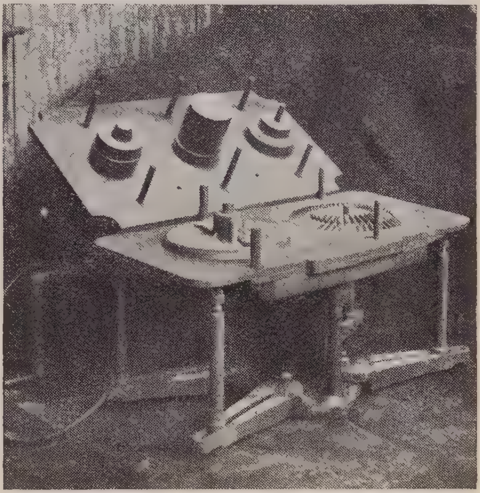

FIG. 14.—STRIPPING-PLATE PATTERN FOR PRODUCING COPE, MIDDLE PART, AND DRAG IN ONE CYCLE OF OPERATIONS.

In each instance the stripping plate is an essential feature, the ordinary spur wheel being a fairly common example involving the simple movement of lowering the pattern through the stripping plate by means of a plunger, but the helical and spiral wheels require different mechanism to actuate their withdrawal. This can be accomplished by two methods, the first being that of mounting the pattern in such a manner which allows it to rotate freely on a centre spindle, the twisting movement necessary on withdrawal being effected by the stripping plate as the pattern is lowered. The second is similar, with one exception; this is in the form of a spring-loaded twisting action of the pattern, the function of the stripping plate in the latter instance is that of controlling the movement of the pattern during the operation of withdrawal.

Pedal-Operated Stripping Patterns

Fig. 16 is that of a small pedal-operated stripping plate machine designed specially for the production of multiple moulds, a complete set of which is shown in foreground together with a pair of castings. It will be appreciated that patterns of such design can at times present many difficulties when considered from a quantity production standpoint, and may involve a departure from orthodox pattern-making principles.

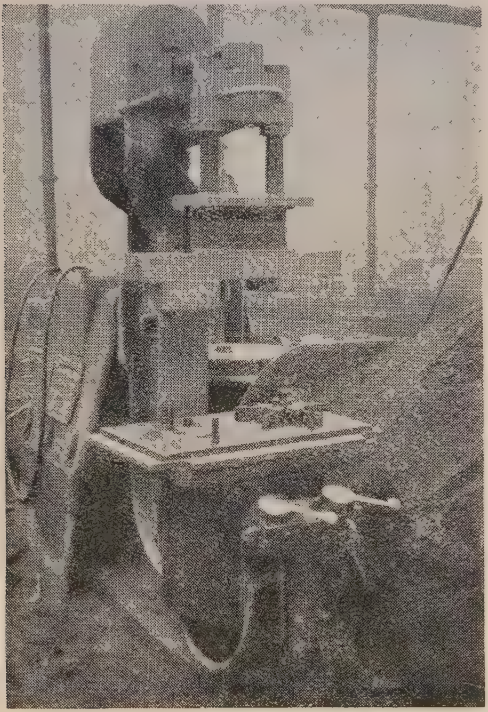

FIG. 14a.—PATTERN LAYOUT FOR PRODUCING COPE AND DRAG MOULDS, ON JOLT SQUEEZE TURNOVER MACHINE.

The earlier patterns of this type were designed for hand moulding, and comprised of four sections, as shown by the example in foreground of photograph; this was necessary in order to facilitate its withdrawal from the mould. Increasing demand, far in excess of hand-moulding possibilities, necessitated a drastic change in moulding methods, which was successfully accomplished by the designing of a simple but very efficient pedal-stripping machine. Its construction consists of a stripping plate bolted to a table, the pattern being held in ramming position by a spring-loaded plunger connected to a foot pedal which, when pressed withdraws the pattern, and when released pushes it back sharply to the ramming position. The reason for the foot operation is to leave both hands of the operator at liberty for ramming, which is done by series of sharp blows by the fists, and the joint face is produced by rotating a small three-armed strickle on a central spindle, the cycle of operations to produce one mould section taking only a few seconds. This example is a typical instance in which the stripping plate is an essential feature of the pattern equipment.

Adaptor Frames

Although pattern plates of the double-sided type are very popular in repetition foundries where hand-moulding methods are employed, and in many cases where small squeezing type machines are used, beyond this their limit of usefulness appears to end, especially where the moulding machines are of the joint turnover type. Such, however, is not the case, as these patterns can be used in conjunction with an adaptor frame.

The function of the frame, which must correspond in size to that of the moulding boxes in use on any particular machine, is that of providing a machine-faced receptacle for the pattern plate, and must have a depth slightly in excess of the deepest pattern likely to be used. This excess in depth is necessary to keep the pattern clear of the jolt table, the frame is designed with eight lugs on the top face and two lugs on the bottom face.

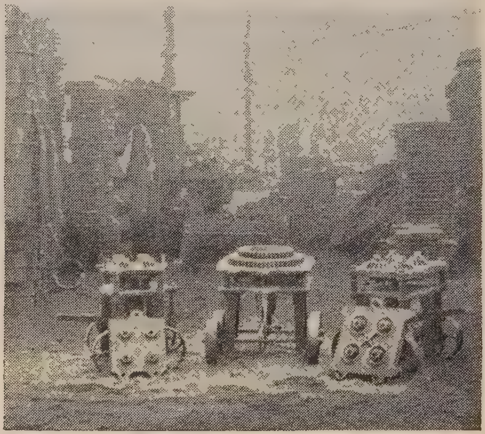

FIG. 15.—GROUP OF STRIPPING PLATE MACHINES FOR PRODUCING STRAIGHT, HELICAL AND SPIRAL GEARWHEELS.

The bottom lugs are at each end of the frame and are used for bolting it to jolt table, those on the top face serve a dual purpose, two of them being in a central position at each end of the frame provide the means of locating the pattern plate, the remaining six being equally disposed round the frame provide effective facilities for bolting down the pattern plate.

An illustration of several sizes of adaptor frames are seen in Fig. 17. Fig. 18 shows an adaptor frame and pattern assembled on the table of a jolt turnover machine.

Patterns Fitted with Down Runners

It may be interesting to note that all pattern plates used on machines of the jolt turnover type are fitted with tapered runner pins, also riser and vent pins where necessary, and each pattern has a special press plate with a clearance hole drilled in a position corresponding to that of the running pin and a small pouring basin fitted to it. The advantage gained by using a special press plate in conjunction with patterns fitted with runner pins results in the production of top part moulds complete with runner and pouring basin in one cycle of operations.

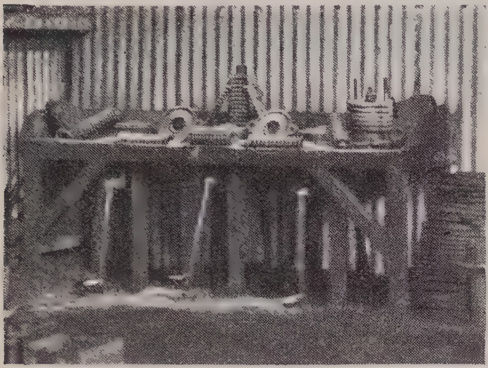

Fig. 16.—Group of Pedal Stripping Machines for the production of Multiple Mould Sections.

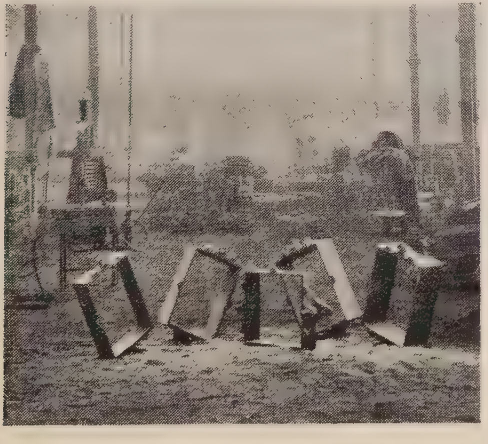

Fig. 17.—Group of Adaptor Frames.

Deep Draw Machines

It must be pointed out that the adaptor frame method requires moulding machines of the deep draw type, this being due to the fact that the depth of frame reduces the useful distance between jolt table and press head; nevertheless the small extra cost of the machines is more than justified when the substantial economies of pattern-plate production is taken into consideration.

Although the author is fully aware that many more different types of pattern equipment are in general use, some of which possess features peculiar to certain classes of work, by choosing the examples described in this Paper an endeavour has been made to represent a reasonable cross section of pattern equipment used in foundries engaged in quantity production of small and medium castings.

In conclusion, the author wishes to express his thanks to the directors of Bamfords, Limited, for permission to use their patterns for the purpose of this Paper, and also to Mr. A. Cotterill who kindly assisted by taking the photographs.

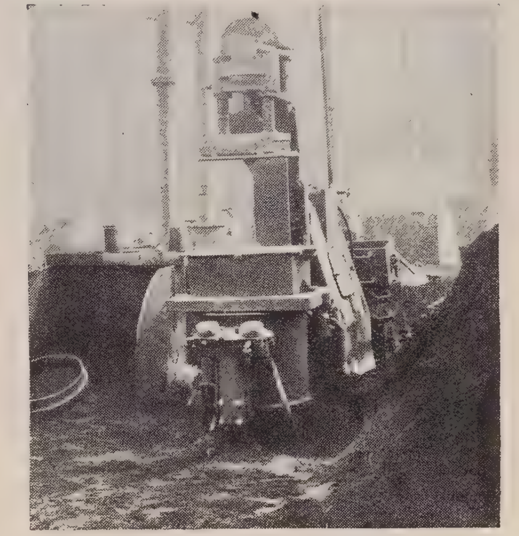

Fig. 18.—Adaptor Frame and Pattern Plate assembled on Turnover Jolt Machine.

DISCUSSION

Mr. F. Dunleavy congratulated Mr. Butters on the excellent lay-out of his pattern equipment and moulding machines, and suggested that a problem which required serious attention was the necessity for the speedy removal of the moulds from the machine, if the moulding machine was to be used to anything approaching total capacity. This was a problem beyond the scope of the Paper, but he felt it was one which was interwoven with the present subject. Could Mr. Butters give a little information on mould output, labour employed and floor space required for a specific job?

Mr. Butters, in reply, said Mr. Dunleavy had gone beyond the scope of the Paper altogether. No attempt had been made to indicate methods for mould removal. Actually the moulders work probably a minimum of 8½ hrs. per day, and can produce in the region of 100 moulds, the length of row being 18 by six deep, totalling 108 moulds, which is a full day's work. The area of floor space allotted to each moulding machine was approximately 400 sq. ft.

The "Split Mould" Method

MR. J. C. HALLAMORE asked for a further explanation of the "split mould" method for the production of plate patterns.

MR. BUTTERS, in reply, gave as an illustration the mould for an ordinary pulley. By placing a flat top on each of the two half-moulds it produced two half-patterns from one complete mould. Obviously, as the size and complexity of designs increased, this method became more complicated. Nevertheless, it was a really efficient and economical method of producing a pair of pattern plates from one mould.

MR. J. HOLLAND asked if it would not have been better to have cut out the expense of core-boxes in making these "split mould" patterns. He suggested two further tops ought to have been moulded off the two bottoms; that was by using four parts. Then the sectional thickness would have been more uniform, strengthening ribs being cut in the mould or formed by wood strips. Regarding dowelling, the method shown would be satisfactory in the case where moulding boxes were drilled to suit the pattern plate, but if the pattern plate must be made to suit existing boxes, some other method seemed necessary. When recently producing a twin cast plate, the method used was to cast a steel dowel in each corner of one plate with bushes to correspond in the other plate. From this location the pinholes to suit the existing box were jig drilled. These plates were cast in aluminium.

MR. BUTTERS, referring to Mr. Holland's remarks as to the making of the pattern so that it would lift its own ribs to eliminate cores, said his practice was not to make any special core-boxes for these patterns. They were cut by the pattern moulder to whatever shape he wished them to be. It was quite a workable proposition and he had not tackled the job in the way Mr. Holland suggested. He used the method explained in the Paper, and achieved reasonably good results. It was not a long job to carve the blocks out to suit the joints, and leave spaces in the cores to make supporting ribs. He thought his method was the quicker, and he could not see any improvement along the lines suggested.

His second point regarding two pairs of boxes being used would necessitate placing the pattern back in the top mould, a practice which should never be encouraged, as there was always the danger of damaging the mould impression. The method to ensure perfect matching of the two half-patterns, namely, by using four doubly countersunk discs, was very similar to his own method, with one important exception; this was, that countersunk discs were much cheaper to produce than steel dowels and bushes.

Metal Patterns

MR. H. PINCHIN said Mr. Butters had outlined the various materials for the production of pattern equipment. For the lighter patterns he (the speaker) used non-ferrous metals, brass or aluminium, and not cast iron. He considered that cast iron would probably be a more satisfactory material, because, in the event of accidental rough usage, the non-ferrous patterns might distort. Damage to cast iron would most likely cause breakage, which was immediately noticed, but with a ductile material slight distortion might not be noticed before a dozen or more moulds had been produced, which in quantity production would cause a considerable amount of waste. Regarding thin section patterns, and the resultant chilling at the extreme edges, he thought anyone making this type of casting in cast iron would have available a suitable mixture which would eliminate this trouble.

MR. BUTTERS said the use of brass for very small patterns not only eliminated the chilling of very fine edges, but it also allowed the spray type of patterns to be built up by soldering. In the case of aluminium, there was a distinct advantage when the fatigue factor was considered, especially at the present time, where female labour was employed.

Corrosion of Metal Patterns

MR. J. ROXBURGH referred initially to the question of the double-sided pattern plate. It was rather a difficult matter to ensure that such a pattern plate was perfectly straight. When Mr. Butters referred to supporting a double-sided pattern plate, which was black, on the machined surface of an adaptor piece, it must of necessity follow that the pattern plate should be straight and flat. He wondered if Mr. Butters would indicate what precautions he took in order to ensure that his double-sided pattern plate was straight.

With regard to the use of proprietary pattern compounds for making oddsides for machine moulding, Mr. Butters did not specify the particular metal used for the patterns anchored in such compounds. He thought the lecturer should have issued a warning here in respect to this as it was well known that some compounds corrode certain metals.

In the use of four pin-lift machines, of the type described by Mr. Butters, it was obvious that it was more difficult to push the mould up off the patterns than it was to withdraw the patterns from the mould. In consequence of this he asked what experience Mr. Butters had had, as regards good and bad "lifts," and also with reference to the finish of his patterns, their accuracy and the amount of taper he usually allowed.

Avoiding Distorted Patterns

In reply to Mr. Roxburgh's comments, MR. BUTTERS said that he did not experience much trouble in keeping the pattern plates straight. He did, however, have cause to reject a plate about a fortnight ago, which was cambered $\frac{3}{16}$ in. The size of the plate was 12 in. by 18 in. and the patterns were of very simple design. After careful investigation it was noticed that the pattern plate had been run with a spray runner on each of the long sides, and a riser on each end. It was decided that the plate be made again in the same manner with the exception of the risers, which were omitted. This casting was perfectly straight and sound, which proved fairly conclusively that the camber or bend in the first casting was caused by the risers restricting the contraction of the plate.

Regarding the plates that have slight irregularities, such as $\frac{1}{32}$ in. of twist or camber, they were studded in the corner affected, so that the plate rested firmly on the machined frame. He had very few studded pattern plates. In some instances, when plating patterns of very heavy sections, it was necessary to bare the plate where the heavy sections occurred, in order to equalise the rate of cooling, otherwise there was a serious danger of internal stress or, worse still, the plate may fracture on cooling.

On the question of metals used in conjunction with compounds, his experience was rather limited, as the only compounds he had used were plaster of paris and cement with cast-iron patterns embedded in them. These patterns stood up to normal foundry service conditions very well, the corrosion of the patterns being negligible. With reference to pin-lift machines, he quite agreed it was more difficult to push moulds off than to draw the pattern from the mould. Nevertheless, consistently good results could be obtained provided that the machines were kept in good order. It was, of course, necessary to have the moulding boxes machined, and the finish must of necessity be good. The taper allowance was generally about $\frac{1}{8}$ in. to 1 ft.

Wood and Aluminium Composite Patterns

MR. J. E. COOKE said that Mr. Butters had supplied substantial information regarding metal patterns made in cast iron, but points of advantage possessed by brass patterns were the ability to build up sheet or extruded sections, and the very fine finish obtainable. The ease with which repair could be carried out often offsets their greater liability to damage.

Aluminium patterns were often regarded as unsatisfactory on account of their tendency to corrosion, but over very long periods dimensional loss was extremely slight where brushing off and varnishing the plant were regularly practised. Indeed maintenance and care in handling all metal patterns amply repayed extra trouble necessitated.

In these days it was a national duty to economise on the use of all non-ferrous metals, and this Paper has suggested several methods that can be used to advantage. A successful method of reducing the metal section of cast aluminium patterns was to place a wooden block in the mould and cast a mere shell of aluminium around it. The surface of the timber was only slightly charred during the casting operation, and the timber interior afforded a very convenient means of attaching the pattern to the pattern plate by means of wood screws. Where metal patterns were embedded in any of the "stone compounds" trouble may be caused through either contraction, sweating, expansion, or corrosion through chemical reaction.

MR. BUTTERS, in reply, referred to the corrosion of aluminium patterns, and agreed that with periodical varnishing such patterns had an extremely long service life.

Control in the Repetition Foundry*

By A. B. BILL (Associate Member)

The introduction of repetition machining methods, for the development of which the automobile and allied industries have been largely responsible, has made demands on the foundries for large-scale production of castings, supplied in regular and reliable quantities, to ensure the continuity of production so essential to such industries. Exacting specifications for material, both chemical and physical, machinability, soundness and dimensional and profile accuracy are enforced, and it is incumbent upon those foundries to which the work is entrusted to fulfil such requirements and to ensure that rejections shall be as low as possible, so as to cause the minimum interruption of the flow through machining lines.

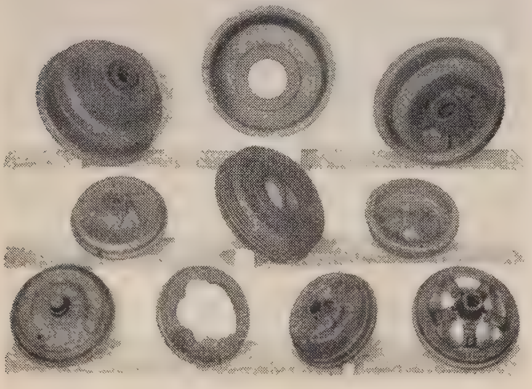

FIG. 1.—HUBS AND BRAKE DRUMS FOR AUTOMOBILE ENGINEERS.

There is, of course, a divergence of opinion as to what constitutes a "repetition foundry"—indeed, often amongst older foundrymen, no such place is admitted to exist. The author, however, is not alone in the opinion that where plant and tackle can be laid out to the best advantage to produce a succession of small or medium weight castings, with the minimum exercise of the moulders' and coremakers' skill and the maximum exercise of the art of planning and co-ordination of effort, such an organisation may well be termed a "repetition foundry."

Differences between Foundries

The jobbing foundry produces a variety of castings, usually with small quantities off, and with the least expensive pattern equipment; often quite different from any job made previously, so that only the general experience of its executives can be of assistance in determining the method of procedure. This type of work calls for the highest commendation and demands the greatest skill on the part of the moulders and coremakers and all concerned with their production. Semi-repetition of larger jobs is carried out, however, and has been ably demonstrated by Whitehouse, where special box parts, cut down to pattern joints, were illustrated, together with turnover boards, etc., which, it is claimed, have resulted in large savings in ramming times. Even here, however, it is stressed that the individual skill of the moulder is of the highest importance, and that even the sand mixture used is in his hands, each man mixing a sand to suit his own ramming inclinations and the particular job.

In the repetition foundry, however, it is the fact that semi-skilled labour is largely employed (particularly since the advent of the war), which demands that each piece of tackle provided, each material used, and each operation carried out, shall be rigidly controlled at as many points as possible.

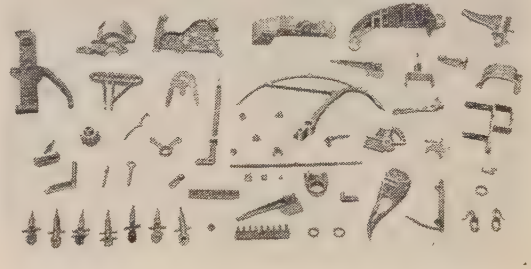

FIG. 2.—CASTINGS FOR AGRICULTURAL ENGINEERS.

The foundry with which the author is associated produces many thousands of castings per week in "blackheart" malleable iron from hundreds of different patterns, by a variety of methods, ranging from "spray" and "oddside" to jolt squeeze rollover machines. Examples of these are shown in Figs. 1 to 3. The following remarks, therefore, will of necessity be influenced by this association, but at the same time will apply to repetition work generally.

With this class of work, the job to be set out for production has to be studied carefully and the method of production decided upon, which may depend on the size or probable extent of the order, the intricacy or otherwise of the job, or perhaps the particular type of moulding machine available. Again, the decision as to whether the job is planned completely upon receipt of an inquiry may depend on the probability of an order to follow, and to some extent upon the scope of the planning department. If it is possible to do so, then a complete planning of the job while still in the inquiry stage is preferable for at least two reasons. First, because the job will be ready to go into immediate production upon receipt of the order and avoid delay, and, secondly, since careful study of the job may suggest slight alterations in design, either to facilitate moulding or to economise on cost of production.

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* The author was awarded a Diploma for this Paper.

Liquid Shrinkage

With steel castings, or malleable castings, the method of running and feeding in relation to disposition of mass and relative sections must be decided upon. Methods of trial and error are too costly for modern production, and whilst minor adjustments may be necessary after the initial layout, it is only rarely that trouble due to shrinkage should appear when once a job reaches the production stage. In order to overcome liquid shrinkage due to high initial freezing points and a short freezing range, top and side feeders may be used to provide reservoirs from which the casting can draw its supply of molten metal; these are quite a straightforward and obvious solution. Examples of these are shown in Figs. 4 and 5.

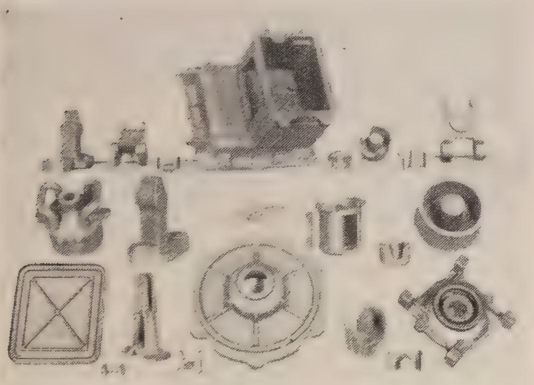

FIG. 3.—CASTINGS FOR ELECTRICAL ENGINEERS.

The position of such feeders for a given casting is often too obvious to need comment, and whether a top or side feeder is used is sometimes determined by the amount of room in the flask. While a top feeder may mean a small flask and less floor space, difficulties will arise if the feeders are not filled sufficiently. Shrinkage difficulties caused by inequalities in adjacent sections of metal generally give far more trouble, and it is here that co-operation between customer and foundry may mean prevention or at least improvement.

Redesigning Castings

Indeed the vagaries of the designer are responsible for many of the awkward problems which beset the foundry, and many castings could be made sounder, simpler and more economical to produce by slight alterations in design which would not impair their efficiency. When, however, the only solution to a difficulty is cure and not prevention, the expedients adopted may be many and varied, *e.g.*, ribs, or whole sections may need thickening up to keep them fluid long enough to allow feeding metal to find its way through to a heavy boss; an illustration of this is shown in Fig. 6. A pad may be necessary for the same purpose and subsequently removed. Bosses might have been cored out to reduce their mass, and the necessity for feeding may need heavy densening with the attendant dangers of blow holes and cold " shuts."

Hot Tears

Pulling or " hot tearing," a defect which although not wholly peculiar to malleable is probably encountered more in the founding of this material than any other, calls for special consideration. While tearing in a radius may often be overcome by increasing the fillet (or radius), a " tie " or thin bracket of metal is probably the only method of dealing with hot tears round the periphery of a casting. The elimination of internal tears, which may be caused by hard rammed cores, may necessitate considerable reduction in the bulk of cores, and in extreme cases a complete split through the core with its accompanying difficulties of registering and location.

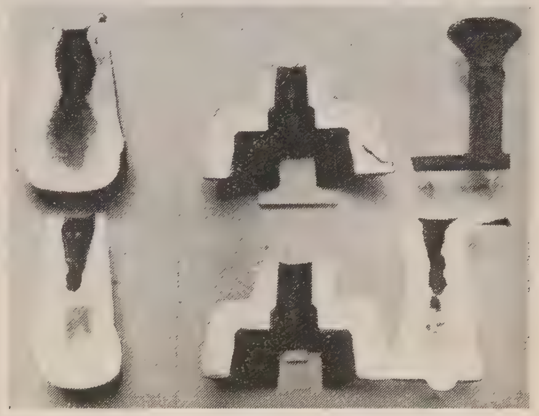

FIG. 4.—SHOWING EFFECT (ABOVE) OF SHRINKAGE DUE TO SEPARATE RUNNER AND FEEDER, AND (BELOW) SOUND CASTING WHEN RUN INTO FEEDER.

Any resistance to contraction from solid shrinkage must be minimised to prevent cracking or distortion. It may be necessary to knock off certain feeders hot or to provide a period of slow cooling, by placing the castings in a muffle as soon as possible after casting. It is now general practice for most of the large consumers of castings to submit machining location drawings with their initial inquiries. This permits the foundry to consider the suggested points of location, intelligent criticism is welcomed, and if the layout does not meet with the requirements of the foundry, helpful co-operation is usually forthcoming to solve any difficulties to mutual satisfaction.

In order to ensure that location points decided upon are kept constant and clear, they should, wherever possible, be moulded, preferably in the bottom of the mould. The position of a core, or core assembly, is not so positive as the mould itself, and trouble may be experienced due to misplacement of cores forming part of locations. All these points need careful thought and must be considered when the job is planned initially.

Runners and Feeders included in Pattern Equipment

Finally, when the method of production has been decided upon it should be adhered to, and such denseners, feeders and ties as may be necessary should become an integral part of the pattern equipment, as is shown in Figs. 7 and 8, and not left to the discretion of the moulder.

Efficient pattern equipment is, of course, essential for easy and rapid production and close co-operation between foundry and patternshop can do much to avoid "wasters" or loss of time during production. The patternshop has the job of making the tackle and of necessity has an eye to its cost, just as the foundry manager must look to his moulding costs. To temper this desire for cheapening equipment, however, it should be remembered that it is in the foundry that it is put to the test and that the cheapest and simplest equipment does not necessarily mean the most efficient moulding.

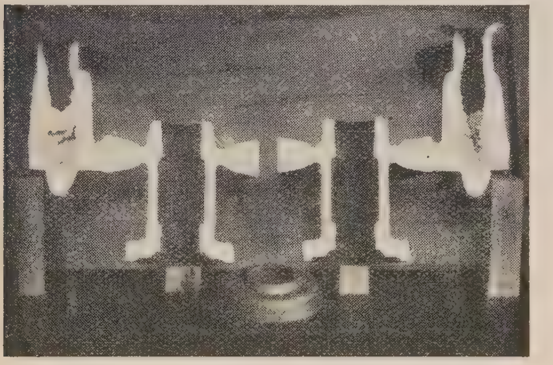

FIG. 5.—LEFT: SOUND CASTING WHEN BOTTOM PORTION IS CHILLED TO EQUALISE COOLING RATES AND PROVIDE PROGRESSIVE AND DIRECTIONAL SOLIDIFICATION. RIGHT: SHRINKAGE DUE TO DIFFERENT COOLING RATES AND INABILITY OF FEEDING HEAD TO GET THROUGH THIN CENTRE SECTION DUE TO RAPID FREEZING.

Pattern plates, for example, must be strong enough to withstand the rough usage inevitable in the foundry. Prints and registers should be adequate and well matched and enough general taper and root fillets should be allowed on the pattern to ensure an easy draw. Much valuable moulding time can be lost patching dragged moulds, apart from the danger of loose sand inclusions, and in many cases it pays to scrap a damaged mould.

Mould Patching

This is particularly noticeable with the use of synthetic sand mixtures which do not lend themselves readily to patching. From the danger of washing, due to soft ramming or blow-holes or scabs from hard ramming, it is often more economical to ram a separate core up in the mould to replace a deep cod or pocket, despite the added cost of the corebox and coremaking time and materials. Many loose pieces, too, are better replaced by cores, although the loose pieces may at first appear to be the obvious method of moulding. Locating cores (Fig. 9) are a more certain check for registering than soft sand prints where they can be used, and also facilitate moulding. Especially is this the case with bottom printed cores forming machined bores.

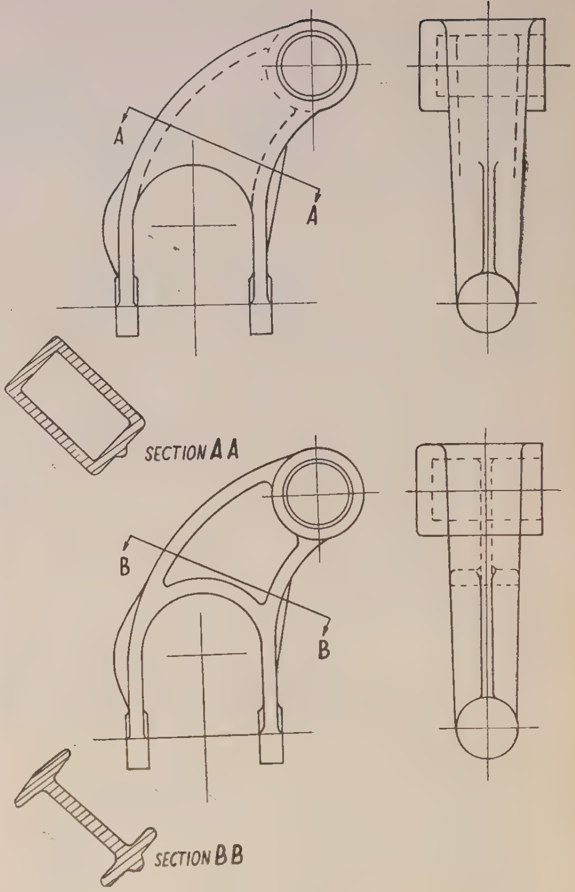

FIG. 6.—ALTERNATIVE DESIGNS FOR LAMP BRACKET CASTINGS.

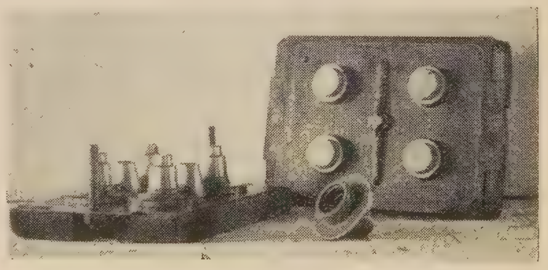

FIG. 7.—SHOWING WELL-BUILT PATTERN EQUIPMENT, METAL PATTERNS MOUNTED ON PLATE AND BOARD FROM JOLT SQUEEZE. RUNNERS AND FEEDERS INTEGRAL.

Once the job gets into production other problems are always the constant companion of the foundryman and some reference will be made to them, although it is not proposed to attempt to go into any great detail. In so far as actual moulding practice is concerned, for example, it would be superfluous to comment on the variety of defects which can arise from an even greater variety of causes, but particular mention can be made of the necessity for controlled ramming. From the study of many carefully prepared analyses of foundry scrap it can be safely said that improper ramming has been the cause of as many rejects as any other single factor. Particularly with the use of naturally-bonded sand, hard ramming, sometimes of only a portion of the mould, with its consequent impermeability and inevitable blowholes or scabs, is a prolific scrap maker.

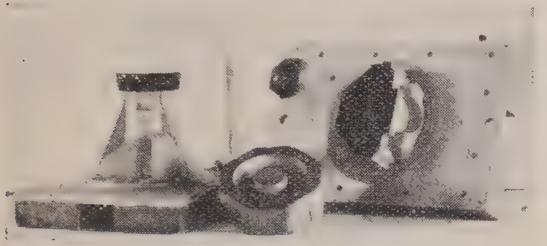

FIG. 8.—SHOWING PATTERN EQUIPMENT TOGETHER WITH BOX FOR CENTRING CORE FOR VERTICALLY LOCATED BARREL CORE.

The use of the ordinary vent wire is slow and has a devastating effect on patterns on production moulding, apart from the fact that it is difficult to judge exactly where to apply the wire. A jig to fit over the box and punch real vents, instead of useless "whistlers," is easier and quicker to apply than the manually operated vent wire (Fig. 10) and soon pays for itself in a reduction of waste, besides safeguarding the pattern.

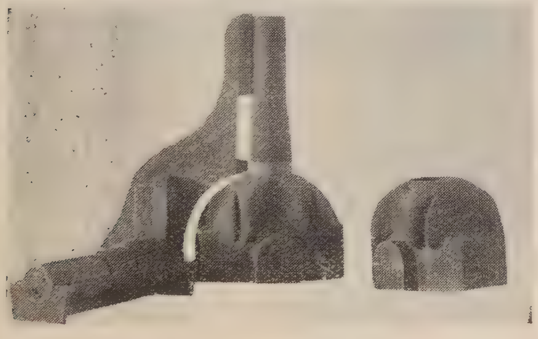

FIG. 9.—SHOWING CORES ASSEMBLED BEFORE LOCATING IN MOULD WITH SIMPLE GAUGE TO CHECK FOR CONCENTRICITY, ALSO METAL SHELL DRYER FOR BARREL CORE.

Sand Control

Controlled ramming and proper venting should be corollaries to a carefully prepared moulding sand, delivered to the moulder with almost foolproof characteristics. It should be as permeable as is compatible with strength; refractory, and sufficiently elastic to cover unavoidable differences in ramming density and mould sections. Coal dust in facing sand should be constant for a given class of work and sufficient to prevent face impermeability and scabbing as well as to assist cleaning operations and any subsequent machining. Much has been written in the past on the subject of sand control and it is not proposed to enter into any detail here. It would appear that an artificially-bonded sand lends itself more readily to control than natural sands, and it is certain that in the foundry with which the author is associated, careful control of a synthetic mixture, kept within predetermined limits of moisture content, compression strength and permeability, has resulted in almost complete freedom from defects which can be directly attributed to the moulding sand. This sand contains less moisture than the natural sand, has good green bond strength and is 4 to 5 times more permeable.

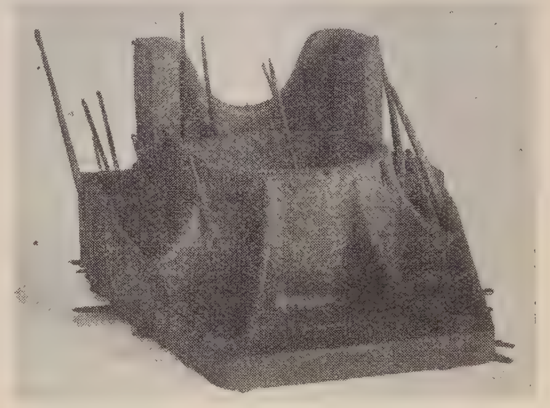

FIG. 10.—SHOWING EFFECTS OF INEFFICIENT MANUAL VENTING.

Added Importance of Cores

Due, in large measure, to the intricacies of modern designs, cores play an increasingly important part in the foundry, and although it is not necessary, here, to comment on the actual art of core production, something may be said of the details, small in themselves, which do give trouble and increase rejections. Core flash (Fig. 11), particularly noticeable with blown-up cores, or from badly registering loose pieces in the corebox, is often difficult to remove, but may leave a slot in the casting necessitating welding which is more costly than a little initial care.

Core drying, thanks to the efforts of the stove manufacturers, is something taken almost for granted, but soft undried cores do appear sometimes, or improperly dried oil-sand cores may absorb moisture from the air if left for any length of time. These if sagged should be rejected, or, if not, redried. Open vents (Fig. 12) and crushing cavities should be stopped off and a close clean skin insisted upon.

Assemblies of two or more cores, or half-cores, should be checked by a simple jig or gauge, particularly from the danger of worn strickles or strickled faces on the corebox. In some cases, particularly with fairly large half-cores, it pays to leave a small amount of excess sand on the joint face and locate the core in a rubbing jig, which is a facsimile of the mould prints, in order to ensure accuracy. This phase is shown in Figs. 13 and 14.

How much core inspection should be left to the moulder himself, and how much should be part of the coreshop inspection department will depend largely on the need for dimensional accuracy of the particular job. The piecework moulder will in his own interests see that any core he uses is visually perfect, but it will be acknowledged that his job is moulding and not inspection, and that in the main he should be freed from responsibility for cores. Dimensionally important cores should be checked by gauging where necessary, and cores which do not conform to gauge rejected. It should be demanded that registers or "go by's" are clearly defined and intact.

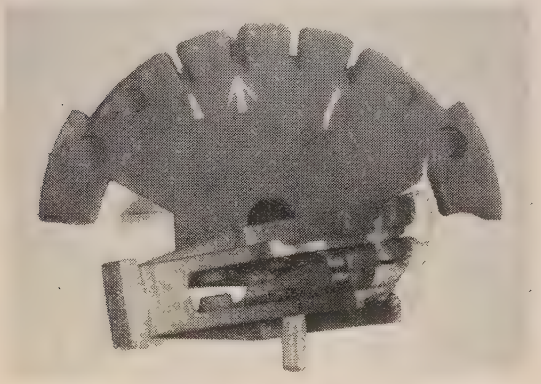

FIG. 11.—SHOWING FLASH LEFT ON CORE AND RESULTANT SLOTS IN BRAKE SHOE CASTING.

Jig Setting of Cores

Great care should be taken in locating cores in the mould, and again a simple jig or gauge (Fig. 15) is of value, particularly with cores which have of necessity only a small print bearing, as, for example, barrel cores located vertically. Repetition machining allows for only a very limited amount of locational error, and the machine shop is chary of increasing allowances to overcome discrepancies. Surely no machine shop reject is more heartbreaking than an otherwise perfect casting, free from blow holes and porosity, which has failed to clean up during machining.

Equal emphasis is placed on the necessity for correct location of snap flasks, box parts, and the registering of assembly pins, box pins and bushes in order to prevent off-set castings. Pattern equipment should be cleaned frequently, and careful inspection made for general wear and tear or loosening of dowels; particularly it should be noted that brackets and fillets, so necessary to prevent tearing or cracking, have not been broken away.

Inspection Department

Having considered various defects and their origin in the foundry, the author desires to deal fully with the actual internal castings inspection department, to discuss its routine activities, and more particularly its scope, and to point out something of its value to the foundry executives. The primary function of the inspection department, it will be agreed, is to reject those castings which would obviously be rejected by the customer or machine shop, if allowed to pass on.

This, however, is only the commencement of the duties of the internal inspection and, as was pointed out editorially in "The Foundry Trade Journal" of October 31, 1940, "the type of inspector whose sole object in life is to condemn as much material as possible as being defective has no place in any progressive organisation." Indeed, a department which held that object only in view might well prove more of a liability than an asset. At the same time, its constant endeavour should be to ensure that each casting released to the customer is, as far as can be ascertained visually, perfect within the limits usually associated with it.

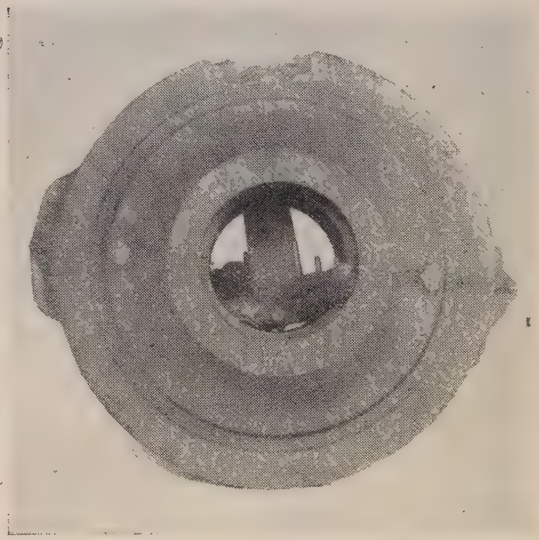

FIG. 12.—SHOWING EFFECTS OF OPEN VENTS IN CORE.

Quality and finish should be kept as far as possible to predetermined standards, and a system of "Go" and "Not go" gauges built up to ensure dimensional accuracy. Apart from this primary job of inspection, however, there are many ways in which the department can help in the reduction of foundry scrap. A regular analysis of castings passing through the department should, if possible, be returned to the foundry, showing the number passed on, the number rejected and the reason for rejection. Whether this is done for every casting made, and whether it is a daily or weekly analysis, will depend to some extent on the scope of the department, the nature of the particular job, and how much scrap is habitually made. Apart from this record, however, rejects should always be on view in the department, so that they may be seen and discussed by the foundry foreman concerned. This will ensure that he agrees they should be rejected, and also that there is agreement as to the cause of rejection so that steps can be taken to minimise the possibility of a recurrence of the trouble.

Notification of Faults

Due to the inevitable time lag between moulding and inspection (which, even in highly mechanised units must amount to the time necessary to allow for cooling and cleaning), immediate notification of faults, together with a sample showing the defect must be made to the foundry foreman concerned. A delay of only a few minutes may mean another box of potential scrap put down on the floor. Obviously, in manually operated foundries, the delay will be longer and waste of time more serious, except that, with batch melting, it may be possible to prevent the casting of definite waster boxes, and so save melting costs and perhaps cores.

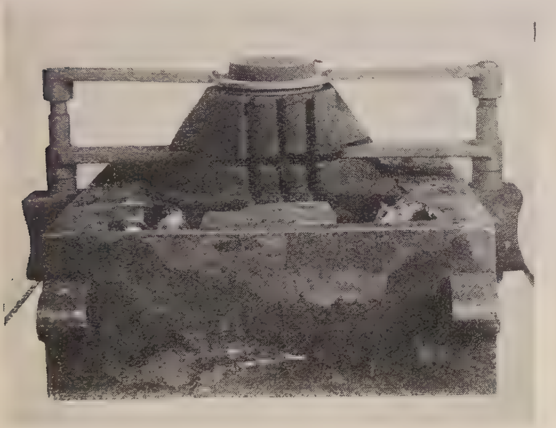

FIG. 13.—SHOWING LOCATION OF TWO HALF CORES IN PLASTER FACSIMILE OF MOULD PRINT WITH SIMPLE STRAP GAUGE LOCATING ON PIN TO ENSURE CONCENTRICITY.

If a defect can be definitely attributed to the coreshop, then the coreshop, too, should be notified, since production there will be ahead of moulding and waste of time and material more expensive. Daily and weekly assessments of defects are made on the forms shown on Charts I and II, the figures of which are obviously hypothetical.

Pattern Inspection

Although pattern equipment should be checked over before a pattern is put into work, after a period in the pattern stores a sample casting should be inspected and passed before the foundry proceeds with the bulk order. The sample may show up faults which will save the first day's production from rejection or perhaps the cost of subsequent rectification. Even though the pattern is not new and thousands of castings may have been successfully made before, it does not always follow, after a prolonged stay in the stores, that the new castings made from it will be of the same quality as the previous batch.

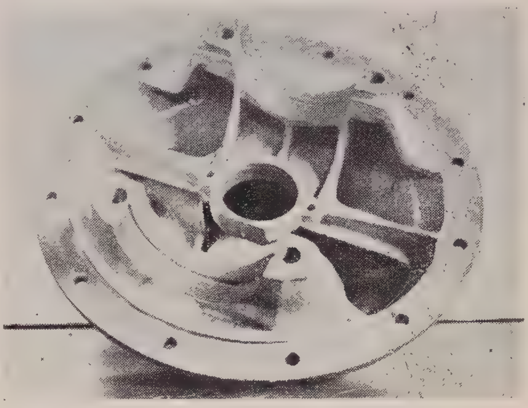

FIG. 14.—CASTING FROM FIG. 1 MACHINED UP ILLUSTRATING NEED FOR ACCURACY.

During transit from stores to foundry a thin metal flange may have been accidentally bent, a necessary fillet may have been removed during renovation; a new coat of varnish may cover an indication that a certain boss is to be chilled. Possibly a bad bruise may have escaped the attention of the foundry foreman or moulder.

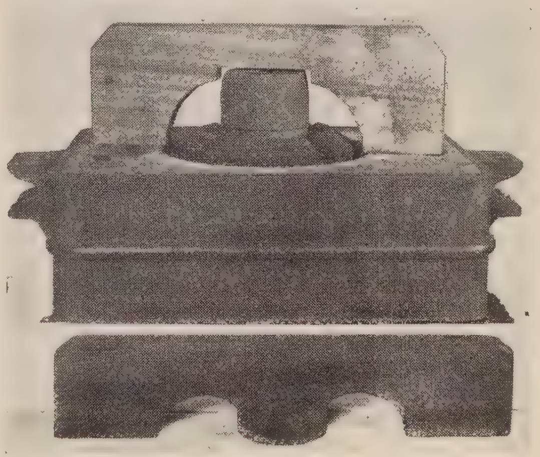

FIG. 15.—SHOWING LOCATION OF CORES IN MOULD CHECKED BY SIMPLE STRAP GAUGES. (THIS IS THE " ROSETTE " CORE REFERRED TO IN DISCUSSION.)

Despite the efforts of the patternshop to provide adequate printing and simple location and registering, intricately cored jobs often have their own little peculiarities which only experience can illustrate. This is particularly so where it is not possible to assemble cores before coring up and where all are located separately in the mould. Where the prints are not foolproof, a certain core may need holding down in a particular way to avoid eccentricity; another may need judicious filing to prevent crushing.

Breaking up the sample will reveal inside defects, such as blowholes, deep slag inclusions or shrinkage. Steel and low-carbon irons may show contraction tears necessitating " ties " or brackets which cannot conveniently be fixed to the pattern and need to be cut by the moulder either in the mould or the core.

Typical simple weekly scrap analysis. One moulder only showing cause of rejection.
Scrap Analysis—W/E. 21/11/39.
Customer : Jones. Part No. 43267. Moulder : Smith.

Weigh.	Blown.	Mis run.	Mis-placed core.	Sand incl.	Slag incl.	Broken in.	Crack.	Swollen.	Total rejects.	Good casts.
1st	7	0	2	0	2	0	1	1	13	64
2nd	9	1	1	1	1	1	1	0	15	44
3rd	3	0	1	0	1	0	0	0	5	53
4th	8	0	1	0	7	2	0	4	22	45
5th	7	0	0	0	4	0	0	1	12	72
Total	34	1	5	1	15	3	2	6	67	278

Percentage rejected : 19·4. Remarks : Blown.

Defects Exaggeration by Metal Differences

Moreover, a sample may show up tendencies towards faults, which is of as much value as the showing up of actual defects. Although laboratory control of the metal is of necessity so close as to need no comment, variations can, and do, take place in melting conditions and the resultant temperature of the metal. Thus, a slight draw in a casting poured from to-day's relatively cool metal may become a wide open tear with to-morrow's hotter iron. Conversely, a slight skin blister from to-day's hot iron may mean a bad blowhole from to-morrow's sluggish metal. Slight core misplacement usually develops, if not checked immediately. The presence of small amounts of loose sand inclusions often points to a badly registering core, which may need easing slightly in the print to prevent the possibility of a batch of oversize cores, either from a badly worked corebox or due to spreading while green, crushing the mould badly.

Typical simple daily scrap analysis. Five moulders making the same job, showing causes of rejection.
Scrap analysis—W/E. 16/11/39.
Customer : Jones. Part No. 43267. Moulder : Smith, etc.

Man.	Blown.	Mis run.	Mis-placed core.	Sand incl.	Slag incl.	Broken in.	Crack.	Swollen.	Total rejects.	Good casts.
" X "	3	1	1	3	1	1	0	0	10	41
" S "	7	0	0	1	1	0	0	0	9	39
" N "	3	0	0	0	2	0	1	1	7	15
" Q "	6	0	6	0	2	0	0	1	15	36
" T "	4	0	5	2	5	0	0	2	18	41
Total	23	1	12	6	11	1	1	4	59	172

Percentage rejected : 25·5. Remarks : Blown.

Fettling Considerations

Again, for the benefit of the grindery and fettling shop, attention to size and disposition of runners and feeder heads, the reduction of unnecessary " flash " due to worn coreboxes or faulty core location and the checking of slight misplacements and cross-joints can considerably reduce fettling costs. Too much enthusiasm on the moulder's part in rubbing or filing cores to prevent crushing, or the cutting of too large or unnecessary " ties," are both points well worth the attention of the inspectors. Badly placed core wires fused into the casting take time to remove, and the same applies to sprigs, used for holding down cores, which are left standing proud of the core and become fused. Care should be taken to see that these are always sleeked over.

It is perhaps a small point, but even the despatch department can benefit from a careful check on the clarity of the customer's trade mark and part number. This is especially so where there is a marked similarity between two patterns or a right- and left-hand pattern of the same job. A distinct number is a more certain check than any amount of familiarity with the particular job. Clean, distinct part numbers are of assistance to the customer, too, since many parts for replacement are ordered from them by number as well as a description of the part.

The inspection department may find it difficult to persuade the foundry to remedy small defects and irregularities, for two reasons. First, because it may be considered that a job is too urgent to be held up for minor details which do not affect the utility of the product and are only a matter of finish. Secondly, because the foundry is often only too happy to get the job past the rigours of inspection without worrying any more than is necessary about processes which have to follow.

From the customers' point of view, the inspection department must help by conforming rigidly to any particular dimensions asked for, particularly where these are unavoidably determined by cores whose position can vary. Care must be taken to see that machining location points are kept clear whether they are moulded or are of necessity cored. Offset castings should be rejected unless they can be cheaply rectified or the customers consulted to ascertain whether they would be prepared to accept the faulty castings in a batch and alter their location to suit discrepancies.

Quality of material, machinability, or perhaps speedy production may be salient features in the sale of castings, but quality of finish and attention to customers' special requirements will at least improve relations, and should not be overlooked as a contributary feature.

More Co-operation

Finally, the closest liaison between the customer and the foundry should be maintained to their mutual benefit. Routine visits by a responsible executive should be maintained, during which detail changes of design which may become necessary can be discussed in relation to their effect on production. In order to rectify defects speedily, either of dimensional inaccuracies revealed during jigging and location or material defects during machining, a regular record and analysis of machine shop rejects and their causes, is essential, and will usually be found to bear close relation to the internal scrap record.

The author has endeavoured to outline some of the features necessary to ensure the regular production of a reliable product and to safeguard the possibility of releasing to the customer any defective castings, whatever the defect may be. From the initial layout of the job and sampling, through all the manufacturing processes to the final inspection of the castings, he advocates as close and rigid a control as may be deemed necessary, in order, not only to maintain the standard of work but to keep the executives of the foundry in touch, promptly and regularly, with any defects, tendencies or deviations from standard of quality. This not only maintains the reputation of the product, but assists in avoiding internal waste and inefficiency. Particularly, a thorough detailed inspection which, while it may not be a stage of production, will surely pay for its introduction.

In conclusion, the author would like to express his thanks to the directors and management of Ley's Malleable Castings Company, Limited, Derby, for permission to publish this Paper and for the loan of slides, also to Mr. J. Roxburgh, foundry manager, for his encouragement.

VOTE OF THANKS

MR. A. JACKSON, in proposing a vote of thanks, said that the Paper was of particular importance to all those who were in normal times engaged in the production of heavy repetition work.

MR. J. LOWE, in seconding, remarked that there were certain methods of checking mentioned in the Paper with which he did not necessarily agree, and suggested the adoption of simpler methods for some jobs. He had not seen a scab on a casting for 17 years when made in a moulding machine. Hand-ramming, for which he did not care, was liable to cause scabs. It was essential to provide the machine moulder with suitable facing sand, as it represented about 75 per cent. of his job, if he had any skill at all.

DISCUSSION

MR. BILL briefly thanked the meeting, and commented upon the statement of Mr. Lowe that he had not seen a scab for a long time when using a power-operated machine. He was quite prepared to accept the statement, but he noticed that Mr. Lowe had subsequently said that the moulder should be supplied with a suitably-prepared sand. This latter point was one which had been referred to in the Paper. If the moulder was not serviced, scabs would occur, especially in the case of low-carbon irons. Mr. Bill also pointed out that in his own case high temperature and a certain amount of penetration made it necessary to use sand having a small grain size associated with fairly hard ramming.

Venting Foolproof Sands

MR. HAROLD HAYNES asked why moulds should be vented if there was foolproof sand. He said it was sometimes found that a core-box would have to be made wrongly on account of the shrinkage of the core. Had Mr. Bill found this to be necessary in order to make his cores fit into the moulds? He could not agree with Mr. Bill's statement respecting liquid shrinkage in the casting illustrated by Fig. 4. He noticed the porosity was located at the bottom, where there was a runner. Was it the runner which was causing the porosity, or the metal employed?

MR. BILL agreed that it did seem somewhat strange to say that, even with a supply of foolproof sand, venting was still required. Although his firm were providing their moulders, to a very great extent, with a really good synthetic sand mixture, with a permeability, putting it on the safe side, of more than 50 A.F.A., nevertheless trouble ensued if a certain amount of venting was not undertaken. This applied particularly to flat, shallow jobs or on deep tapered cods where ramming was difficult to control. He was convinced, however, that quite a considerable amount of venting which was done to-day was carried on more from force of habit than from necessity. While some moulders could not be persuaded to use vents, it would be a good thing if others could be persuaded not to use them. Everybody would agree that too many vents were better than no vents at all, where they were necessary, but at the same time care should be taken to make effective and not merely useless whistlers.

MR. HAYNES said that it was not economical to interrupt the work of mass production, and therefore venting should be eliminated.

MR. BILL agreed, but said that there were many cases where venting could not be dispensed with no matter what the permeability and strength of the sand might be. He hoped that someone would be able to state the reason, and also perhaps someone might be able to state whether there really was a "foolproof" sand. The suppliers of some of the artificial clays for synthetic sands informed them they could work to 3 per cent. moisture, but so far they had had to allow for at least 4 per cent. With the excess moisture the amount of gases generated increased, thus reducing the effective permeability. He had had some small experience of designing himself. Since he had been entirely associated with the foundry, he had reflected that if he had only known what difficulties some of the designs he had made would create for the foundrymen, he would have endeavoured to deal with them differently. As a matter of personal pride, the average draughtsman liked his design to be symmetrical and to "look nice," and then the foundrymen perhaps objected to his design stating that it would be difficult to run it at a particular point. Nowadays, however, designers were found to be very amenable to suggestions of slight alterations in their designs, thus facilitating moulding operations.

Core-Working Difficulties

He had been asked a very vexed question as to whether a core was made wrongly in order to get the casting right. In the first place, his firm did not make any very big cores, and therefore there was not a great degree of shrinkage experienced. It was found that by the use of suitable carriers, whether they were of sand, metal or composition, no real trouble was experienced with sagging, although in extreme cases it was necessary to provide for this, and unfortunately it generally reduced itself to a matter of trial and error.

As to the question as to whether it was the runner which was creating the porosity indicated in Fig. 4, the runner bore no relation to its actual position on the job. It was simply and solely a case of the feeder being too small for the job.

MR. HAYNES thought the running was wrongly located. He personally would run the casting from the top.

MR. BILL replied that it was not a grey iron job, it was white iron for blackheart malleable. One difficulty with regard to top running would be the scouring effect of the metal. Runners were invariably placed on the joint line or at the bottom due partly to the risk of scouring and partly for feeding reasons.

In the case of the second example (Fig. 5), showing shrinkage, Mr. Bill explained that the reason for it was that the solidification of the casting was not progressive. The rapid freezing of the thin barrel-shaped centre portion precluded the possibility of feeding metal, passing through to the relatively heavy boss at the bottom. In order to equalise the cooling rates, therefore, a "chill" was used in the bottom. A feeder placed on the heavy flange at the top was sufficient to feed the centre section and the flange.

In reply to a question from MR. A. SUTCLIFFE, MR. BILL pointed out that his reply to Mr. Haynes covered the point. The casting referred to had a certain amount of liquid shrinkage to make up. Had it been of relatively even sections then no matter where the feeder was placed it would supply feeding metal, or rather it would supply metal to make up for the liquid shrinkage of the casting. Unfortunately, the section was so thin at one part, that before the feeding metal had had time to get through to feed the shrinkage, freezing occurred, and the feeder could only feed the top flange. This difficulty could perhaps have been overcome if the customer or the designer had been willing to thicken that particular part of the section; the whole casting would then freeze more or less progressively. Unfortunately, they would not agree to this course being adopted. An alternative perhaps would have been to put in an extra feeder, but that was obviously not an economical proposition. Thus the rates of cooling were equalised by a densener so that the thin section could not draw feeding metal from the bottom section, and had to draw all its feeding metal from the top.

Filing of Cores Unnecessary

MR. SUTCLIFFE said he noticed that Mr. Bill did not do much mating of cores. The case of the long barrel core was one where it could be done with advantage. Then again, if there was a straight print on the bottom of a mould how would the moulder insert a core without sometimes loosening some sand if he did not taper it by filing?

MR. BILL replied that if a patternmaker made his pattern properly, allowing plenty of taper and plenty of venting, the moulder would be able to insert his core satisfactorily without disturbing any sand. If a mechanised foundry was as well equipped as it should be there should be no such faults as that; they could always be corrected in time. Referring to the mating and filing of the cores, he agreed that in the case of a jobbing foundry (if it was to be admitted there was such an establishment), the file was an indispensable moulder's tool. In the case of the repetition foundry, which Mr. Sutcliffe apparently despised, he did not think this should be necessary at all, since the ideal pattern equipment, cores, etc., should register properly without any cutting and carving by the moulder.

MR. SUTCLIFFE said it should not be necessary on any small job such as was shown in Fig. 4.

MR. BILL replied that this was a point he had made when he stated that prints and registers should be adequate and well matched. If they were, then surely there should be no necessity for filing.

Coming to perhaps a more important point in Mr. Sutcliffe's remarks, he quite agreed that work in a repetition foundry could run itself. This was the sole object of its planning. Credit, however, must be given to the men who made the establishment of the repetition foundry a practical proposition.

Mechanical Venting

MR. A. JACKSON said one illustration of a casting shown was one of which he (the speaker) had seen many examples. Mr. Bill had stated this state of things was overcome by a system of hammering down a spiked plate in order to create a vent. Personally, he (the speaker) did not know whether he had tackled similar jobs on a wrong line or otherwise, but he had entertained a similar idea for a long time, and he had had the unfortunate experience of getting too much "pull-up" with sand. Mr. Bill had not stated in what particular line he rectified the vent by some mechanical means. If he had been able to do so, he (the speaker) would be pleased to learn what it was.

MR. BILL said they never made a venting jig for the particular job illustrated. In the case of the particular foundry with which he was associated, jobs did not lend themselves readily to that sort of thing, because there were so many of them, and it was not practicable to undertake the provision of venting jigs for the numerous jobs which had to be undertaken. Only in a few cases would it be possible to do so.

The first job in which he saw it done was an automobile cylinder, and in that particular case there was a jig which fitted over the pattern pins. It was a relatively elementary job and it had tapered vents, though not a large number of them. The jig came down to $\frac{3}{8}$ in. of the pattern face, and it definitely did away with any manual venting. Jigs had been used, with varying success, in the foundry with which he was associated. The job shown on the screen was definitely a nuisance. Only a relatively small number of castings were made, so that nothing was really done in the matter of inventing a suitable jig. A venting jig had been used on a repetition job, which was a casting weighing about 80 lbs. It was composed of a frame which registered with the pattern pins, but did not entirely cut out manual venting.

Moulding Machinery and Venting

MR. A. L. KEY said it was unnecessary to use a vent wire on a machine-moulded job, if the moulding materials were satisfactory.

MR. BILL replied that if the moulding sand supplied to the moulder possessed reasonably good characteristics, then there might be no need for vents, but, unfortunately, even in the best of well-regulated foundries, the sand which was available was sometimes unsuitable, or at any rate not good enough for repetition moulding. In such cases, vents were necessary, at least in his own particular case. Perhaps half of the total production was effected by means of a synthetic sand mixture with a much higher permeability than that of the rest of the sand used in the foundry which was running on naturally-bonded sands. Vents were definitely required, and in quantity, with naturally-bonded sand. With a sand which was only just strong enough to hold in the boxes, the permeability was so low as to require vents. In the case of a synthetic sand, the permeability was higher, and venting was not so necessary, although often, even with these sands, it was considered advisable to resort to the venting wire. It seemed as though no one had yet produced a moulding machine which would ram a small mould properly, particularly on fairly deep snap flask work; the nearest approach to it being some adaptation of the down-sand frame. Primarily, his own firm was using squeeze, or jolt, or jolt-squeeze machines. There had to be a certain amount of ramming round the outside of the box, and if that was done by semi-skilled or totally unskilled boys, trouble often ensued. Given a perfect moulding machine, with a reasonably good sand, then perhaps there would not be any need for vents, but until that desirable consummation was achieved, there would be.

MR. W. BROWN referred to pulling up sand around the vents. Bath tubs, for instance, carried mechanical vents exactly as described by Mr. Bill. They consisted of a series of taper vents on a grid which, in turn, ran through a second grid. The whole device was operated by means of a crane or mechanically-lifting arrangement. It was registered through the box, and it came up about 3 in., and the secondary jig came up with the lot. The taper allowed the first lift, which was drawn through the holes in the secondary jig, and the whole came together.

The "Rosette" Core

MR. H. MORRIS referred to the "rosette" core (Fig. 15), and pointed out that three cores had been put in the mould. Would it not have been better to have split a core vertically and dry the two halves to form one core instead of using three separate cores and the jig?

MR. BILL thought perhaps it might be pointed out that the object of this illustration was to show the simple gauging of the core rather than the method of making the core.

MR. BILL then drew a diagrammatic sketch of the centre core in question. Referring to it as the "rosette" core, he would not state that it was impossible to make the core by splitting vertically on the centre line, but pointed out that although three cores were used, only two coreboxes were needed since the top and bottom cores were identical. He assumed it was thought easier to dry smaller cores without sagging or trouble due to warped core plates.

It would have entailed the use of loose piece or "draw ins" to make the core in two halves, and suggested that in any case it would be better to leave an excess of sand on the joints of the two dried half cores and rub this off in a jig afterwards to ensure accuracy. Had Mr. Morris considered that the centre core only might have been used and the top and bottom bores moulded?

Cause of Scabbing

MR. KEY asked what was the nature of the scabbing which had been mentioned? Was there a solid scab or a blister scab?

MR. BILL said that opinion was divided. Those of which he had experience in the past, and to a certain extent in the present, particularly in the use of naturally-bonded sands, were due to the impermeability of the backing sand. The gas from the facing sand, whatever it might be, could get through to the backing sand, and could push a small proportion of the facing sand into the casting. He might be wrong about this, and he remembered hearing a very lengthy argument by Mr.

Hird upon the subject; but he firmly believed it was the case; namely, that it was due to the impermeability of the backing sand in cases where both backing and facing sand were used. It might be due to the backing itself, the method of ramming, or to the moulder, or the moulding machine.

MR. KEY asked whether it was a rough part of the casting where the sand had washed away? Was that the appearance of the scab?

MR. BILL said it was not. In the majority of cases it was more or less of a shell of metal over the face of the casting, with little bits of sand scattered about the casting itself. There was a definite lifting of the surface with loose sand or a pocket of sand about the casting.

MR. JACKSON said that was what was termed a blister scab.

MR. KEY asked what control there was with regard to backing sand in respect of moisture?

MR. BILL said it varied according to the sand used, and pointed out that enough moisture had to be allowed to make up for evaporation since it was not kept in bins.

Preparation of Backing Sand

MR. KEY asked whether the backing sand was prepared beforehand, or was its preparation left to the judgement of the moulder or the mixers.

MR. BILL said that in some cases the preparation of the backing sand was left to labourers who just broke down the spent sand, tempered it, and delivered it to the moulder again. In some cases there was a really carefully-prepared sand mixture. In all cases it was prepared and was delivered to the moulder. Of course, with batch melting there was no continuous preparation, and the sand had to stand for a comparatively long time. Therefore it was necessary to resort to a batch preparation of the backing sand.

MR. SUTCLIFFE asked whether the scabbing was on the flat surface?

MR. BILL replied that that was usually the case, but not necessarily, and often occurred on a tapered mould or possibly those made on a jolt machine, being caused by facing sand jolting away from the pattern, leaving part of the face covered only with backing sand.

MR. KEY said there were two forces causing scabs. The sand might be too damp or it might be too dry. If the sand was not sufficiently elastic to take up a surface expansion that was. primarily, a cause of scabs. He referred to surface expansion on the facing sand. Having this in view, it was only a question of pursuing the matter, and he thought a great deal of information would be obtained by the investigator. He had proved his point in a number of cases.

MR. BILL said that, as a matter of fact, he found it difficult to agree wholeheartedly with Mr. Key as to the particular causes mentioned. He found scabs were formed more often with a naturally-bonded sand. The naturally-bonded sands were used again and again, additions being made, of course, to the backing sand and the facing sand, of naturally-bonded sand in which the grain size was definitely very variable. He was under the impression that the majority of experts on sand control agreed that the elasticity of sand depended to some extent upon its grain size, and they agreed that with a mixed grain size, namely, small grains interspersed with large grains, there was a greater ratio of elasticity. It might be assumed that when sand was used over and over again there would be a continual breaking down of the grains.

MR. HAYNES asked whether the patterns were made of metal?

MR. BILL said that some were made of metal, and others of wood.

MR. HAYNES said that ramming, with a springing wood pattern, would cause scabs. Metal patterns for machines were really better.

Patterns for Quantity Production

MR. BILL could not altogether agree that metal patterns were best for machines. He agreed that possibly, in the long run, a metal pattern was best for production moulding. Personally he preferred a metal pattern; but all the same as many as 10,000 moulds had been made off a wooden pattern in his foundry, and it could therefore be considered as being just as good as a metal one, although the pattern needed renovating more often.

Answering Mr. Sutcliffe, MR. BILL stated that the sand was milled. It was considered that what was necessary in the case of a moulding sand was to distribute the bond evenly, or as evenly as possible, over the basic sand grains. The amount of new naturally-bonded sand additions which were made to any particular moulding sand which had been kept for further use depended obviously on the state of the sand. It depended upon its permeability, on the strength of the sand, as to how much bonding strength was given to it. It would not be possible to give a mixture off-hand. There was, of course, no waste of sand at all in the case of synthetic mixtures; proportions of bonding material were added as the strength of the sand deteriorated. The firm with which he was associated had been running the system for a long time now, and he did not think they had wasted any sand at all; in fact, they clung to their spent sand and relied upon it more or less for breaking down grain size in order to furnish a certain amount of elasticity. It was found that with all new synthetic sand mixtures there was a certain amount of difficulty in moulding. They did not appear to flow so well as a naturally-bonded sand, so that the firm clung to their fines in order to improve the elasticity and flowability.

Moulding Problems in the Electric Steel Foundry*

By E. J. KELLY (Member)

The matter in this Paper relates to the work done in the jobbing foundry producing between seven and eight thousand different castings ranging in weight from a few ounces to several tons, including some specialised types of castings. The fundamental principles of moulding are the same for all metals, that is to say, an impression is made of the job to be cast, this may be made wholly from the pattern, pattern and corebox, corebox or boxes, or it may be strickled up as in the case of loam work.

The methods used at the foundry of Brown Lennox include green sand, skin-dried, dry sand, moulds in core and strickle work, and it would be unwise to lay down any definite rule as to which system to use, since a number of foundrymen could receive the same design of pattern, and mould and cast it according to their own practice with the tackle they possessed. Each may produce a good casting in spite of widely divergent methods.

Every new pattern received in the foundry presents its own particular problem, and past experience is invaluable in determining the method to be followed.

Ramming

Sands used in the steelfoundry are of a coarser grain size than would be suitable for iron or non-ferrous work. Ramming, therefore, has to be much firmer in order to obtain a good impression of the job to be cast. This is a most important part of the moulder's craft and can only be gained by actual practical experience. Young steel moulders should be encouraged to ram hard. A well-rammed mould is better able to withstand the inrush of metal and the strains of casting. It requires much less finishing after the withdrawal of the pattern than is the case with a lightly rammed mould. Care must be taken, however, to allow for the contraction of the metal, particularly in intricate castings, and the experienced craftsman will adjust his ramming so as to be strong enough for casting, and yet sufficiently weak to permit contraction.

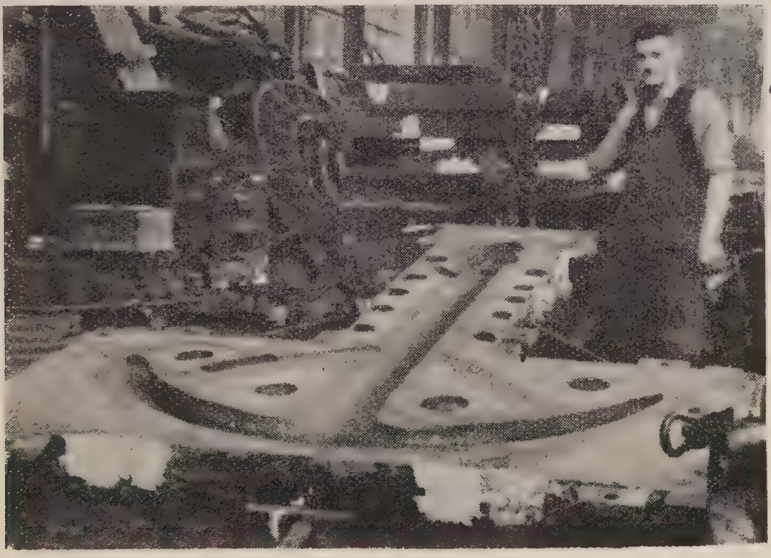

Fig. 1.—Bottom Part of Anchor Mould, with Aids to Contraction in the Mould.

Aids to Contraction in the Mould

Oil sand is advantageous for parts that are likely to give trouble, such as ramming-up pegs and blocks, and the use of sawdust sand; whilst cutting away portions and filling in with weak floor sand also helps. The correct positioning of heads, runners, brackets, chills and denseners, require close attention. Ties may also be cast on jobs such as drums with top and bottom flanges, anchor jaws, casings, and many intricate castings that are required. Ties relieve the mould of part of the contraction strain.

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* The Author was awarded a Diploma for this Paper.

The moulding sand itself must be studied in relation to the design and weight of the job, and careful attention paid to the preparation and testing of sands to be used. Easing bars, cooling portions with water, are extremely useful after the mould has been cast, but as much as possible should be done in the mould itself before casting takes place. An anchor mould showing the complete method of moulding the runner, brackets, easing holes, with the insides of the palms lined with oil sand, is illustrated in Figs. 1 and 2 (Fig. 1, bottom part, and Fig. 2, top part).

Green Sand Moulding

This is practised chiefly on jobs which do not require much machining, or on intricate work to assist contraction. Jobs weighing up to twelve cwts. are cast by this method, whilst many types of castings up to one ton could be so made. Figs. 3 and 4 show sheave moulds, which have been made by the green sand method. Green sand moulds are the truest moulds. They are not liable to distortion, as is the case with dry sand moulds, and if for any reason the pattern has to be replaced in the mould, it may be done without difficulty, and without damaging the impression.

It is the cheapest form of moulding, in that the moulds have not to be stoved and then returned for closing prior to casting, as is the case in dry sand work. It is quite good practice in green sand work to ram up pieces of brick, core or metal on to core-prints, so as to form firm supports for cores, and in the case of studs and chaplets used to support heavy cores, pieces of core, rammed into the mould to form a firm base for such supports, are very useful.

Green sand moulds should be poured as soon as possible after closing, particularly if denseners and chills have to be used. Warm cores should not be placed in a green sand mould. Green sand moulds not cast on the day of making should be parted and left open, to avoid condensation, and only closed prior to casting. Should there be any tendency of the casting to scab or swell near a runner, pieces of oil sand cores can profitably be rammed up in suitable positions.

Small, weak portions of a mould likely to be washed away, or give trouble during pouring may be made as a core off the pattern, with a piece projecting out and then rammed up with the pattern. When the pattern is withdrawn, it becomes a part of the mould carrying the stronger portion. Green sand cores should be used whenever possible as they assist contraction. Attention should be given to the position of runners, in order to direct the inflowing metal in an appropriate direction, so that it enters the mould with the least turbulence, and does not impinge on any core or weak portion of the mould. Runners may be made in cores, and rammed up with the pattern. All these factors assist in ensuring good serviceable green sand moulds.

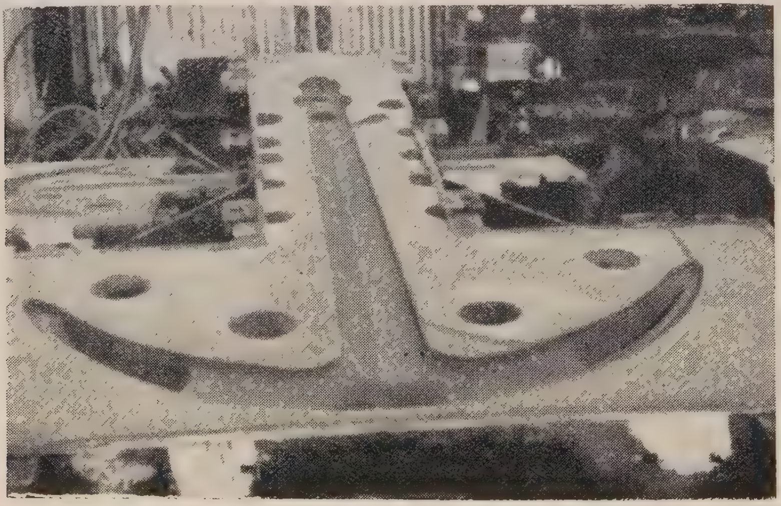

FIG. 2.—TOP PART OF ANCHOR MOULD, SHOWING USE OF OIL SAND BETWEEN THE PALMS, BRACKETS AND BLOCKS RAMMED UP, TO ENSURE THE CASTING BEING FREE FROM PULLS.

Machine moulding lends itself usefully to green-sand work. The patterns with runners and heads specially prepared, give full control of the moulds, which are free from the necessity of repair or retouching. A close study of casting technique and attention to facing and backing sands under strict laboratory control is necessary to obtain full achievement for this excellent method of moulding, which offers unlimited possibilities for the production of highest grade castings.

Skin-drying is practised on intricate work where the moisture in green sand may give trouble. It is also useful in cases where handling tackle and transport to the stove is not available, and on urgently needed jobs where time is a consideration. It is also used in cases where it is desirable to mould and cast in position as made. Many strickled jobs are with advantage skin-dried.

Contraction is more satisfactorily discounted than in dry-sand moulds. Care must be taken not to burn the face of the mould, and time must be given to allow the steam to escape before closing. The mould should not be closed while it is warm. Backing sand should have a low moisture content to avoid moisture striking back to the face of the mould. For the above reasons, it is advisable to cast as soon as possible after closing.

Dry Sand

These moulds are made by the same methods as are used for green sand, but the sand used is stronger, and has a higher moisture content. Larger castings can be made. A better finish with improved machining properties are obtained. Moulds should be thoroughly dried, and as many cores as are conveniently possible should be incorporated in the mould before stoving. Chills and denseners which are required should be provided for while the mould is in the green state, but should not be inserted in the mould, until after it is dried. It is good practice in new work to core up completely in the green state before deciding the best position for feeding or for chills. The larger types of moulds are silica-painted.

Moulds in Cores

This useful and interesting technique is very useful in cases where no suitable boxes are available or where it is desirable to mould and cast in some particular manner. Young apprentices should be encouraged to carry out this class of work. Very small jobs up to 10 lbs. in weight may be cast with a spoon, on the furnace floor. Jobs too large for this method may be grouped together, usually four in a group, and cast together with those weighing a few hundredweights, which, of course, are cast singly.

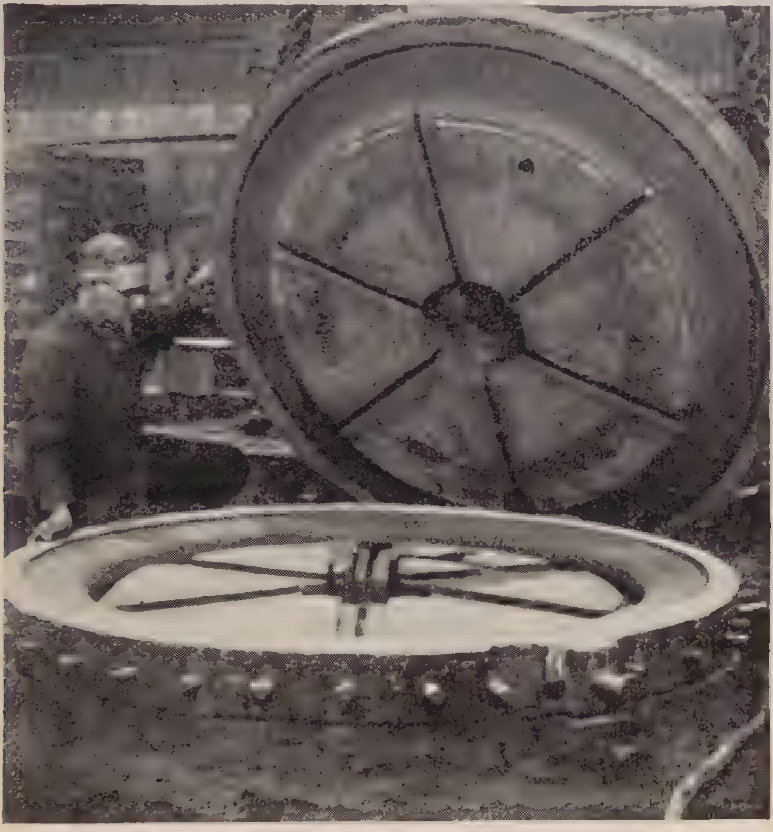

FIG. 3.—GREEN SAND WORK INCLUDES SHEAVES UP TO 10 CWTS.

This branch of moulding is being developed and enables experience to be gained in the correct preparation of moulds for efficient casting. The oil sand used is expensive, but if used only for facing the pattern, runner and heads, a backing of old sand can be used with advantage. The unburnt sand is reclaimed. These moulds do not run if broken, as is the case with ordinary clay-bonded moulds. Several examples of these moulds are shown in Figs. 5 and 6.

Strickle Work

This is a specialised branch of moulding, which many moulders have not the opportunity of learning. It is necessary that the geometry of moulding should be applied at least as far as the moulder is concerned to obtain the most satisfactory results, and the younger moulders should be encouraged to take an interest in this useful branch of the trade and helped to obtain the technical knowledge needed. The sand used is the same as in dry-sand work. Wheel blanks, sheaves, brake rings, drums, covers, clutches, propellers and many oddments met with in the jobbing foundry can be efficiently strickled.

Joint Making

No better examples can be found than those used in machine and plate moulding, where a large number of castings are required off the pattern. Considerable thought is given to the parting planes, that is, where and how the joint is to be made. In the jobbing foundry irregular joints are very common, particularly in cases of whole patterns or with an old casting as pattern when only one or two off are required.

The pattern or casting must be examined in order to decide which is the most convenient place for parting in order to make the joint to obtain satisfactory withdrawal from the mould. The nature of the "lift," associated with the danger of a "crush" when closing, requires careful consideration, for it is here that the moulder must use his skill and art in joint-making to obtain a successful mould. A joint should be so made that, on starting the lift, the top part comes up into space. It should be flat on the parting plane and then well tapered to the joint. Care should be taken to avoid deep and awkward lifts, and thought should be given to the use of loose cods and slip joints. These may help considerably and render the top part simpler and safer to lift and close. Moreover, when finishing off the mould, it may be possible to complete the impression in the bottom part.

Drawbacks

Many examples occur in which a portion of the pattern cannot be withdrawn from the mould. In such cases it may be advantageous to make the obstructing portion of the mould so that it can be drawn back from the pattern in order to permit its withdrawal.

Drawbacks may be very useful in cases where it is desirable to mould and cast in some particular manner, and are most useful when making a mould from an old casting, which, of course, has no loose parts to assist in withdrawal.

Quite often the trouble when using an old casting as a pattern is the difficulty incurred in withdrawing it from the mould. The use of drawbacks may assist in simplifying that problem. The underlying principle for the use of drawbacks is where one cannot for obvious reasons draw a pattern from the mould, or draw the mould from the pattern.

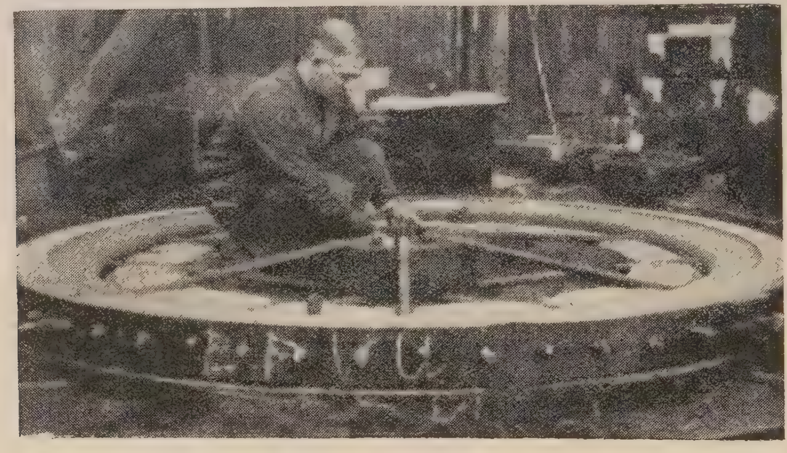

FIG. 4.—SPLIT SHEAVES, WITH MILD-STEEL SPOKES, GREEN SAND RIM WITH CENTRE BOSS IN CORES.

[Here a discussion took place, and the Paper was continued at an adjourned meeting.]

Replies to Questions

The author has been asked several questions since the last meeting about a few of the methods mentioned. For instance, why not have the patterns altered to suit the desired method of moulding and casting? The answer is, the foundry receives a great number of patterns requiring only one, or a small number of castings, off them, and it would seldom warrant the expense of alteration when it is able, by perhaps taking a little more time in moulding, to obtain the small number of castings required; furthermore, the urgency of the job may be such that the time required for alteration would be objectionable. There is also a great deal of useful experience gained by having to overcome some difficulty in the methods described.

The question has also been asked about aids to contraction in the mould. This is a very interesting and important part of the moulders' craft, and some of these problems will be dealt with.

For the benefit of the younger foundrymen, it may usefully be recalled that ramming up a pattern and withdrawing it from the mould is not in itself moulding, it is much more than that. Thought must be given to the runners, heads, chills, denseners, provision for contraction, and correct position and securing of cores, etc.; these form the technique of moulding. With these problems mastered, the neophyte becomes a moulder; without them he has only a job in the foundry. The mention of joint making, loose cods, slip joints, and drawbacks called for quite a number of questions from some of the younger moulders, and it was quite evident that if these could have been illustrated more fully in a practical manner it would have been of considerable interest; there will be some reference to them in what follows.

It should be pointed out that although the foundry has achieved some measure of success with the methods referred to, it also has had its troubles and met with some very stern problems, that required the scientific and

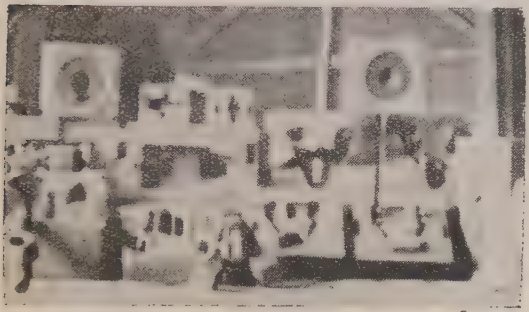

Fig. 5.—Mould in Cores, some of which Weigh Only a Few Ounces.

Fig. 6.—Moulds made in Cores, to gain the Required Position for Casting.

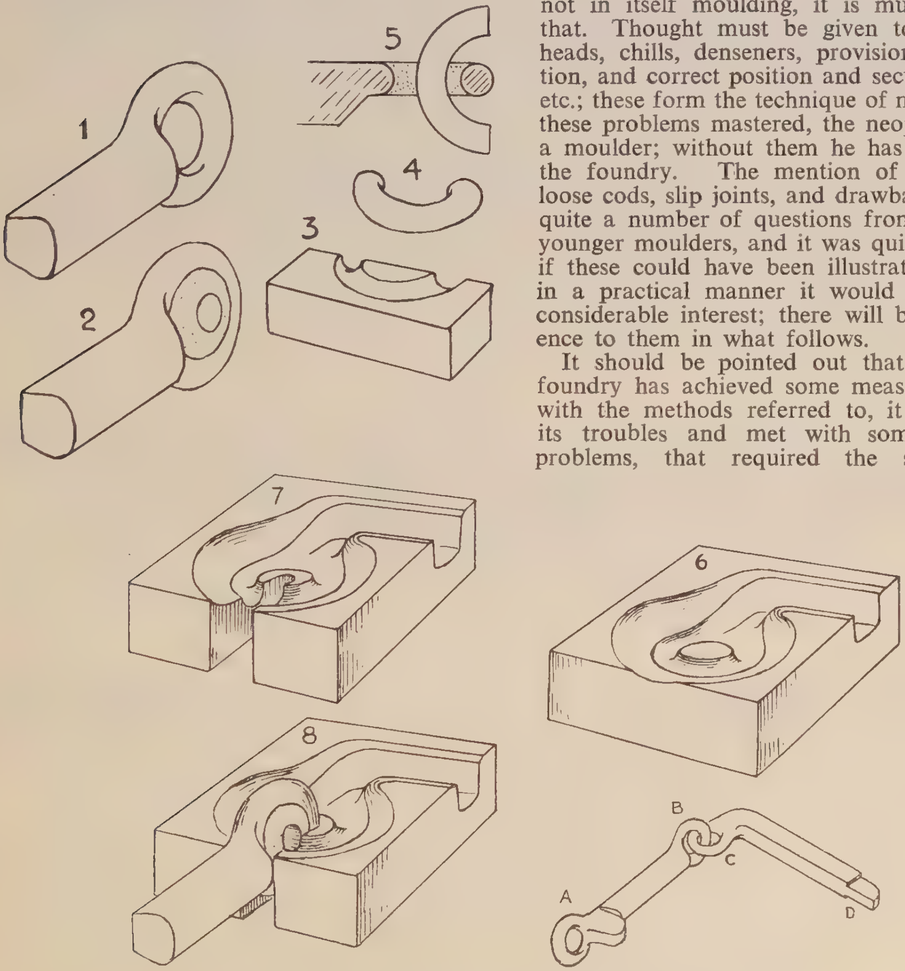

Fig. 7.—Sketches showing the Method used to Link Together Two Components by the Casting Process.

technical knowledge of the foundryman to solve them, and it is only by discussion and keeping a sustained interest in such work that foundrymen can expect to achieve success.

Fig. 7 is a series of sketches detailing the method used for linking together two components by the casting process. The first sketch indicates that two pieces, AB and CD, are to be of cast steel linked together by the eyes at B and C. The piece AB is cast first and is later incorporated in the mould from which CD is cast. The important part of this mould is in the region of the eyes B and C. A mould is made of the eye end of CD. The bottom half is shown at 6. A slot is cut out of both halves of the mould to accommodate the end B of AB. Item 7 shows the bottom half of the mould with the slot cut out.

To prepare the end B of AB for incorporation in mould, the eye is filled with sand and a hole is left to correspond with the cut-away portion of the mould of the eye C. To assist in this operation, a mould of a portion of the eye C is made and a core taken from this, as shown at 3 and 4. The core C is used to form the holes in filling in the eye B. Item 5 shows the core in position of the filled-in eye, and illustrated that the filled-in sand has a stronger section than at first sight appears possible, owing to the differing curvature of the core and materials of the eye. Item 8 shows the prepared eye, placed in position in the lower half of the mould, with the hole a continuation of the ring of the eye (C).

The complete mould is not shown in their sketch. The rest of the mould for the rod CD may, of course, be in the floor, the runner and head being arranged in suitable positions.

DISCUSSION

Mr. J. J. McClelland asked if special provision had to be made for contraction in connection with a sheave that had been shown in Figs. 3 and 4, the sheave in question having the arms cast in with the rims and boss.

Mr. Kelly replied that no special provision had been made at all for the sheave referred to; the job was cast green-sand, and that was all that was needed. It was the custom of some foundries to remove the core from the boss to avoid cracking, but with the use of an oil-sand core this was not necessary. With regard to the sheave with mild-steel spokes cast in, it was a custom to cast the rim first and allow half an hour per foot of diameter before casting the boss.

Mr. W. S. Kinsman asked where the runner for this casting was placed.

Mr. Kelly replied that the runner was sprayed between the arms, the position of the runner being shown in Fig. 3.

Mr. J. F. Gist asked if they experienced any trouble with their moulding sand. He knew of an instance where trouble was being caused in this way.

Mr. Kelly replied that they had a little trouble when the war began, but it was not of a very serious nature; they were unable to obtain the same kind of sand they used previously, and were using entirely new sand. The sand was tested daily by the "Richardson" apparatus. Refractoriness was also being controlled, and thus the foundry was able to remedy any sand troubles almost immediately.

WRITTEN DISCUSSION

Mr. W. L. Hardy wrote:—At the beginning of the section on green-sand moulding, Mr. Kelly stated that "this is practised chiefly on jobs which do not require much machining, or on intricate work, to assist contraction." At the conclusion of this section it is stated that "strict laboratory control is necessary to obtain full achievement for this excellent method of moulding, which offers unlimited possibilities for the production of highest grade castings." These two statements appear contradictory. The latter is, of course, a true representation of the case, but the first statement may give rise to the impression that green-sand moulding, apart from very light castings, can only be used for cheap, rough work.

This is far from being the case. Some steel foundries produce several thousands of castings weekly in green sand, varying in weight from a few pounds to several cwts., and all are subject to extensive machining and very rigid inspection. Even so, many consider that they are only at the beginning of the possibilities of green-sand moulding.

A Member wrote:—Mr. Kelly refers to casting the rim of sheaves with mild-steel spokes and then allowing ½ hr. per ft. before casting the boss. Evidently he forgets that 2-, 3-, 4-, 5- and 6-ft. sheaves average round about the same weight per ft., and therefore the larger the circumference the greater tendency to contract more quickly. Consequently the larger sheaves have a tendency to twist.

Besides, how many foundries are in a position to cast a boss for a 6-ft. dia. sheave 9½ hrs. later? Practical experience over a number of years on such has proved that sheaves up to 4 ft. can be cast, boss and rim simultaneously; 5- and 6-ft. bosses can safely be cast 2 hrs. later.

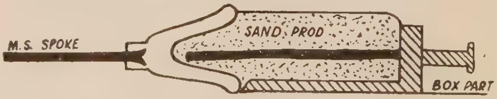

Fig. A.

Colliery headgear sheaves of 16, 17 and 20 ft. are made by casting the rim one day and boss 24 hrs. later. This type of sheave is cast with a green-sand bottom, dry sand tread and top part. Although this type of sheave is swept, adhering to the above rules, I have never known the alignment to be more than ⅛ in. out of truth.

I should like to point out that the tackle illustrated in Fig. 4 is hardly suitable for a jobbing foundry, as, in the event of the depth and width of the sheaves varying, such prod irons are liable to foul the pattern. In my opinion, in Fig. 4 the spokes are let in too near the wearing surface of the tread, with a tendency to chill the casting in parts, causing the rope to fray quickly and also cause irregular wearing of the groove. We always carry our treads with loose irons or prods as shown in Fig. A. These have been set at an angle approximately 30 deg. and about 3 in. apart.

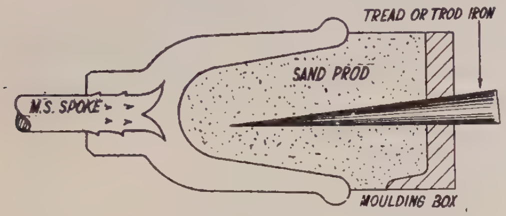

FIG. B

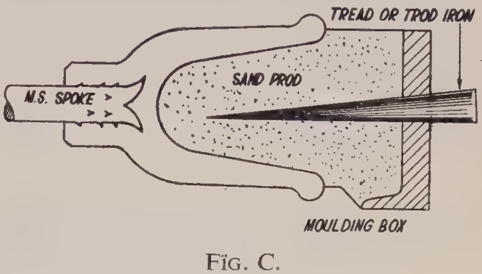

FIG. C.

AUTHOR'S REPLY

In reply, MR. KELLY wrote:—The boss for the 6-ft. sheave would be cast 3 hrs. after the rim. No special merit is claimed for the tackle shown in Fig. 4 of the Paper. The prods are used loosely, the holes being arranged 6 in. apart in the box to receive them. They are positioned and secured as required, and as shown in Fig. B. A useful feature is that the prods are easily withdrawn after the rim has been cast, thereby assisting contraction.

No real difficulty is experienced with the varying depths of treads required. Provision is made by arranging the joint to suit the narrower type of tread.

As shown in Fig. C, the segment packing pieces arranged on the box joints may usefully be employed for those of a deeper nature. The spokes, as shown in Fig. 4, may appear near the mould face, but assurance is given that sufficient metal is allowed for, and no difficulty experienced in the manner suggested.

East Midlands and Lancashire Branches **Paper No. 757**

Fuels and Furnaces for the Heat Treatment of Steel Castings*

By T. R. WALKER, M.A., F.I.C. (Member) and F. SMITH, Assoc. F.

The selection of the type of furnace to carry out a definite duty in a specified place is governed primarily by the nature of the available fuel. If a furnace is properly designed to utilise a particular fuel and is skilfully operated, it will give satisfactory results. With the same qualification, many types of fuels and furnaces can be used successfully. Since heat-treatment is, however, usually only one process in the production of steel articles such as castings and, in addition, is often considered an operation of minor importance, there is a common tendency to pay little attention to the furnaces or their working, so long as delays in output or rejections for inadequate properties do not occur too frequently. This applies more particularly to large furnace installations, fired by producer gas, where it is usually very difficult to arrive at a reliable figure for the operational cost.

Heat energy for industrial furnaces is obtained by the combustion of fuel, or by the conversion of electric energy which, in this country, is generated by the combustion of fuel. The fuels available in quantity may be classified as follow:—

Gaseous—(*a*) Rich gases such as town's gas, coke-oven gas, carburetted water-gas, blue water-gas; (*b*) lean gases such as raw producer gas, clean producer gas, coke producer gas, blast-furnace gas.

Liquids—Light fuel oils, heavy fuel oils, tar oils, tar, pitch.

Solids—Coal or coke on the grate, pulverised coal.

Of the three types, gaseous fuels have advantages over the other two, since they are easily carried to the furnaces. They can be properly mixed with air without previous preparation, and mostly burn without smoke even in a cold furnace. The control of temperature and furnace atmosphere is easiest with gaseous fuels.

Town's Gas and Coke-Oven Gas

These are very similar in analysis and properties, especially as many gasworks nowadays mix large proportions of coke-oven gas with their coal gas. They are produced by the high temperature distillation of bituminous coal and have a gross calorific value of 500/550 B.Th.U. per cub. ft. Owing to the richness of the gas, pipe lines can be small and high flame temperatures can be obtained. The composition and calorific value are almost constant, so that accurate control of temperature and furnace atmosphere is possible. The installation of a furnace to burn these gases requires little additional equipment and is not expensive, whilst the cost of labour attendance and maintenance is low. These fuels are very useful for small and medium size furnace installations, and also wherever furnaces are to be used intermittently, since there is practically no standby expense. The high cost of the fuel is a disadvantage, the importance of which varies in different localities owing to the varying price of the gas.

These gases can, of course, be used only in the neighbourhood of gasworks and coke ovens, whilst the danger of interruptions to the gas supply is undoubtedly a disadvantage in wartime. In some works it has been necessary, owing to the inadequacy of purifying plant at the gasworks, to use crude coke-oven gas. This is liable to give solid deposits in the pipes near the furnace, and especially in the burners, leading to an increased maintenance cost and greater difficulty in maintaining close control of temperature. It also contains a comparatively large amount of sulphur which can be absorbed in the surface layers of articles in the furnace. This type of gas is therefore not suitable for heat-treatment, especially for thin articles the surface area of which is considerable compared with their weight.

Water-Gas

This is produced when steam is blown through coke at a white heat. The reaction cools the coke, which is reheated by a current of air blown through it and allowed to escape. The production of water-gas is thus intermittent unless two generators are used, one making gas while the coke in the other is being reheated. The gas consists of equal volumes of carbon monoxide and hydrogen, with small percentages of impurities such as carbon dioxide and oxygen. In this state it is known as blue water-gas, and has a calorific value of about 300 B.Th.U. per cub. ft. It can also be enriched by the addition of gaseous hydrocarbons derived from the rapid heating of oil to a high temperature. It is then known as carburetted water-gas and has a calorific value of 500 to 500 B.Th.U. per cub. ft. If the gas be so enriched, additional equipment is required to remove suspended tarry matter, and the process of gas-making becomes more complicated.

Compared with other industrially produced gases, water-gas has a high calorific value, giving high flame-temperatures and allowing accurate control of both furnace atmosphere and temperature. It can be burned efficiently and is a clean fuel. On the other hand, the cost of installation of the plant is high and the cycle of manufacture not simple. Facilities must be provided for handling coke and ashes, and the labour cost is high. Thus, the cost of production of the gas becomes a serious one, especially in small installations. It can be cheapened, more particularly in large installations, by the provision of waste-heat boilers, to make steam from the heat otherwise wasted during the heating up of the coke by the air-blast. These boilers increase the capital cost, but decrease the subsequent production cost of the gas. Unless the load on the generators is practically constant, some form of gas holder must be provided to deal with the varying load on the generators. This is an additional item of capital expenditure, but does not appreciably affect production costs subsequently.

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* A Paper circulated to all members of the Institute and read before Meetings of the East Midlands and Lancashire Branches.

Raw Producer Gas

This is made by passing a mixture of air and steam through a layer of red-hot carbon, usually in the form of bituminous coal, though coke, anthracite, wood and other carbonaceous substances can be used if the plant be suitably modified. If the producer be near the furnace, the gas reaching the furnaces is still hot and also contains finely divided tar suspended in it, both of which increase the heating value of the gas. The calorific value of the gas varies considerably according to conditions, but a typical range is from 150 to 170 B.Th.U. per cub. ft., which is low compared with the gases previously considered. On this account, and also because it contains suspended dust particles from the coal as well as particles of tarry hydrocarbons, it must be conducted through flues of large diameter, usually brick-lined, and burned at large ports. As the calorific value of the gas is low, furnaces burning producer gas usually include some arrangement for heating the air required for combustion. This preheating of the air, and frequently of the gas also, is carried out by means of regenerators, normally placed underneath the furnace. These increase the efficiency of the furnace but at the same time increase its capital cost.

As the flow of air and gas through the regenerators is periodically reversed, the air ports at either end of the furnace are of the same size, and the same applies to the gas ports. Since the gases leaving the furnace are much hotter than those entering the furnace they occupy a larger volume, and therefore the velocity of the exit gases is greater than that of the entering gases, so that the entering gases mix comparatively slowly and give a long lazy flame over the charge.

The advantages of producer gas are considerable. The installation cost is lower than that of other industrial gas-making equipment, the operating cost per B.Th.U. is low, and gas making is a reasonably simple process. The plant can be used wherever bituminous coal (or in special circumstances other carbonaceous materials) is available. The disadvantages include the provision of facilities for handling coal and ashes, and the necessity for a steam supply. To obtain the best results, the size of coal must be between fairly definite limits, and the coal must not swell too much on heating. Large gas mains must be used, and these must be cleaned periodically on account of deposits accumulating in them.

Clean Producer Gas

This is prepared by cooling and scrubbing the raw producer gas, a process which removes dust and suspended tarry matter. The cleaned gas will not cause deposits in flues, and makes it possible to use burners instead of ports. The cleaning plant required occupies a substantial amount of room, and demands an adequate supply of water for cooling and washing. The tar, deposited in the form of a viscous liquid, is a commodity for which there is little demand, but it must be regularly disposed of. As the sensible heat of the gas and the combustible tar are both removed, the heating value of the gas is diminished. Since producer gas cools steadily as it passes through mains and gradually deposits tar at the same time, the heating value of raw producer gas decreases progressively as the distance between the producer plant and the furnaces is increased. Thus, the loss in heating value in changing over from raw to clean

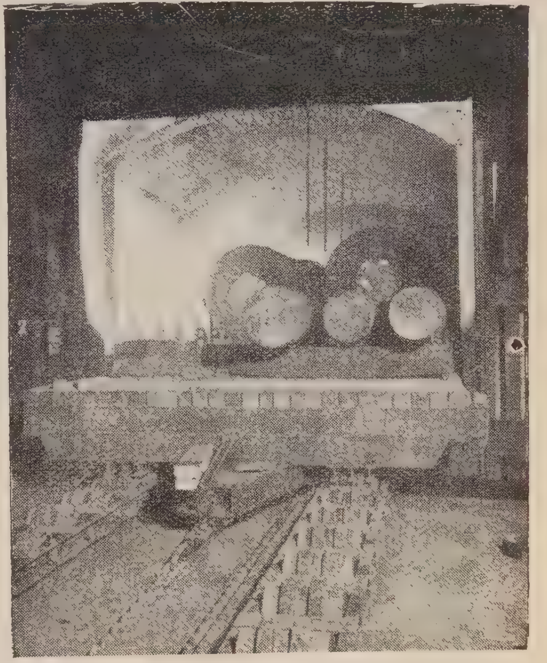

FIG. 1.—LARGE PRODUCER-GAS FIRED FURNACE HEAVY BOGIE.

producer gas in a given plant depends on the relative positions of producers and furnaces.

If a new plant be under consideration, then the capital cost of the furnaces can often be reduced if clean producer gas is used, since comparatively small recuperators, which would soon become stopped up if raw producer gas were used, are often adequate. This helps to pay for the capital cost of the cleaning plant. Clean producer gas permits closer control of furnace atmosphere and temperature, and automatic temperature control can be utilised. This gives a saving in fuel if the plant is carefully operated, and so contributes towards the cost of cleaning the gas.

It is clear that the cost of cleaned producer gas per B.Th.U. is greater than that of raw producer gas, but the actual difference depends on the circumstances of each case. Some advantages of clean producer gas are often difficult to assess monetarily. For example, clean producer gas with a calorific value of, say, 150 B.Th.U. per cub. ft. and town's gas with a calorific value of 500 B.Th.U. per cub. ft., can be mixed in proportions to give a mixed clean gas of any intermediate calorific value, such as 300 B.Th.U. per cub. ft., which is equal to that of blue-water gas. Thus, if there is a shortage of town's gas the supply can be eked out and production maintained, even in a batch of small furnaces with burners of narrow section, without the burners becoming stopped up. If such furnaces, normally operated continuously by clean producer gas, are required for any reason to work intermittently they can be operated, with little alteration in the control settings, by town's gas as an alternative fuel. Similarly, if only one or two such furnaces out of a row are required, they can be put on town's gas without the necessity of operating the gas-producer plant.

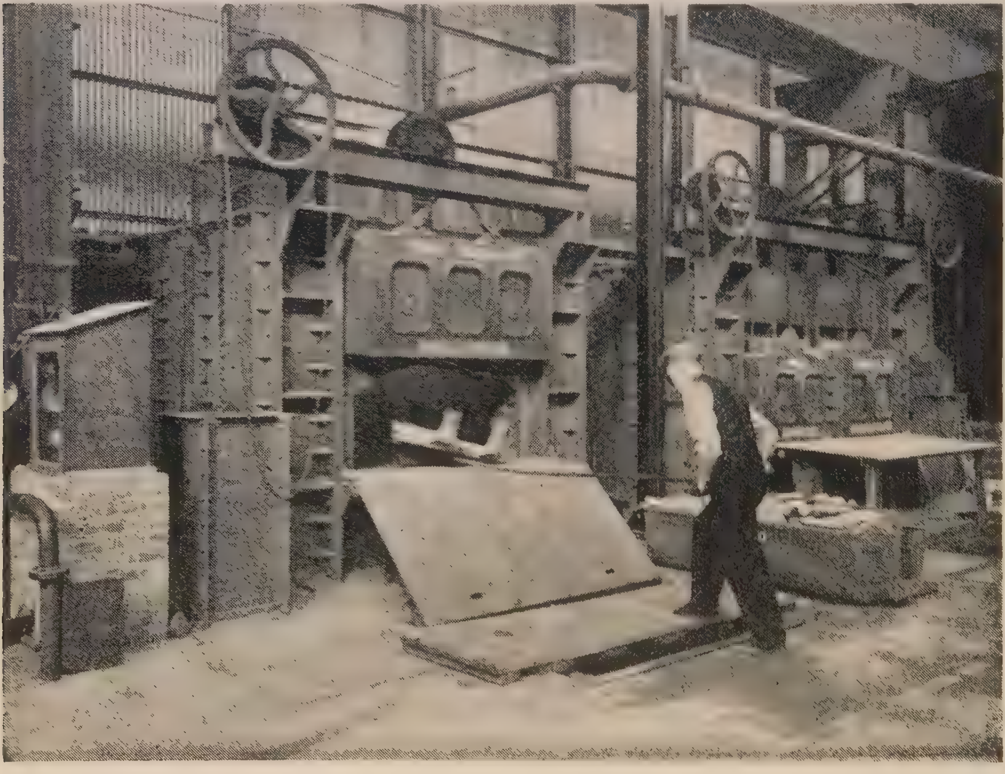

FIG. 2.—SMALL TOWN'S GAS FIRED FURNACES WITH APRON AND TANK.

Coke-Producer Gas

Producer gas can be made by blowing air mixed with steam through red-hot coke instead of coal. The gas resembles raw-coal producer gas except that it contains no suspended tarry compounds, and therefore has a somewhat lower calorific value. When the dust which it contains has been removed, the gas has an almost non-luminous flame and can be ignited at burners like clean coal-producer gas and town's gas. To obtain the best economic results, the furnaces should be fitted with recuperators or regenerators, on account of the low calorific value of the gas.

Coke-producer gas can be conveniently mixed with town's gas to give a fuel with an intermediate calorific value which can be used regularly so long as town's gas is available, and in these circumstances the producer plant can be worked at less than its maximum capacity. If the supply of town's gas be cut off or decreased, gasification at the producer plant can be increased, and the furnace output maintained more or less at its usual figure.

Blast-Furnace Gas

This gas, which is given off during the operation of blast furnaces, is the leanest of industrial gases, having a calorific value of only about 90 B.Th.U. per cub. ft., and is available only in or near works having blast furnaces. It is a by-product fuel and is therefore cheap. Owing to its low calorific value, it must be carried in large mains, and its pressure must often be increased by a booster to obtain sufficient heat in the furnaces. Efficient preheating of the air, and usually of the gas, too, is necessary to obtain high furnace temperatures. Blast-furnace gas is also used for mixing with coke-oven gas to give a mixed gas which can still have a calorific value ample for industrial purposes.

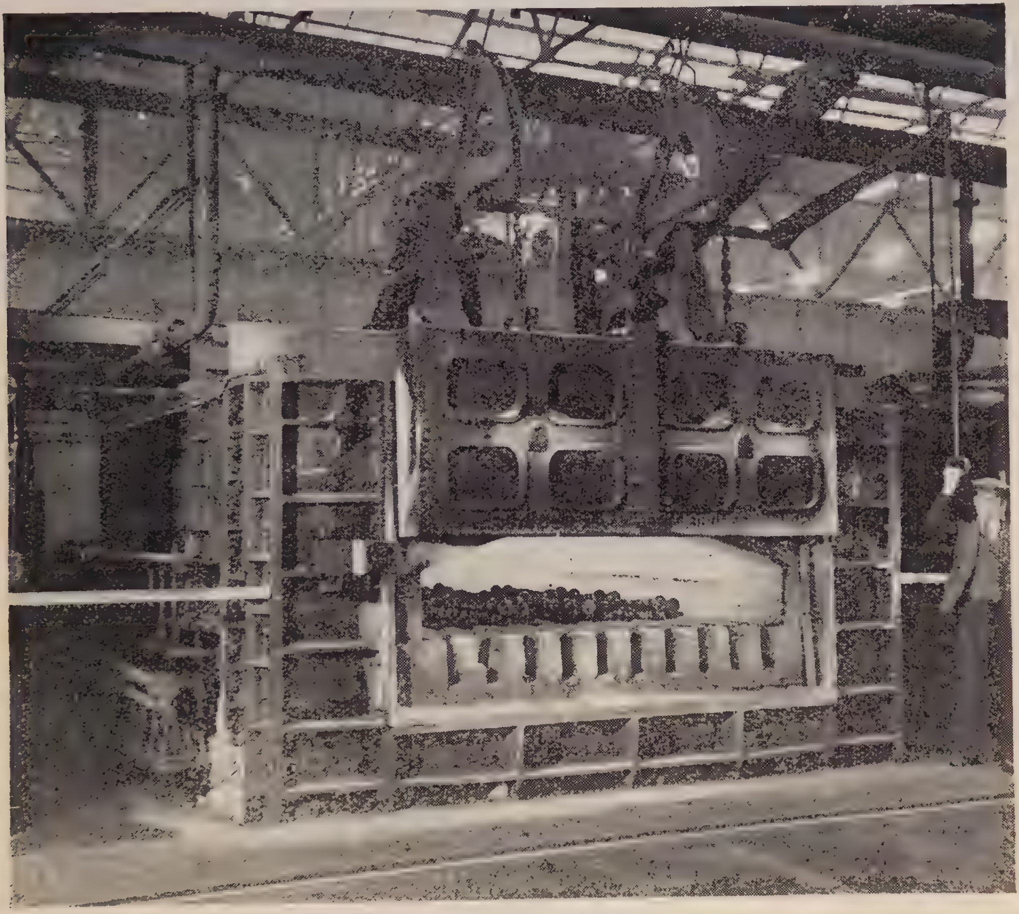

FIG. 3.—TOWN'S GAS FIRED FURNACE WITH PIER HEARTH.

Liquid Fuels

In this country liquid fuels are used much less extensively than gaseous fuels, especially for heat-treatment furnaces. The liquids consist essentially of mixed hydrocarbons derived from two sources:—

(*a*) As products of the fractional distillation of naturally-occurring oils, practically all of which are imported into this country.

(*b*) As mixtures obtained by the treatment of domestic tar liquors, produced in the manufacture of town's or coke-oven gas.

At the present time the number of available liquids is limited, and whilst the supply of some fuels of domestic origin is adequate, that of imported fuels is severely restricted.

The light liquid fuel available at the present time comprises the Pool Board grades known as Pool Fuel Oil and Diesel oil. This Diesel oil is an imported oil, with a calorific value of approximately 19,000 B.Th.U. per lb. and a specific gravity of 0.895, equivalent to 170,000 B.Th.U. per gall. It is, however, required almost entirely for road transport and similar purposes, and little is available as an industrial heating fuel. Creosote B is a Pool grade of heavier oil of domestic origin, with a calorific value of 16,000 B.Th.U. per lb. and a specific gravity of about 1.07, equivalent to 170,000 B.Th.U. per gall. Ample supplies are at present available for industrial heating. Creosote A is a lighter and less viscous fuel, but supplies are by no means plentiful, and continuance of supply cannot be guaranteed. Creosote B/Pitch is a mixture of Creosote B with some of the pitch residue from the distillation of coal, and is more viscous than Creosote B. If supplies of Creosote B became unequal to the demand, the supply of liquid fuel could quickly be increased by extending the use of the Creosote B/Pitch mixture. It is therefore highly advisable, in an oil-burning plant, to cater for the use of both Creosote B and Creosote B/Pitch mixtures.

In order to facilitate handling, these two fuels are loaded hot into a road wagon, and, when received at the consumer's works, are still hot enough to flow satisfactorily. The liquid is usually discharged into storage tanks, from which it is distributed to the furnaces, through a pipe line, or in portable tanks to small overhead tanks serving one or two furnaces. To enable them to flow through pipes, these fuels must be kept at a temperature of from 90 to 100 deg. F., and should be further preheated to about 200 deg. F. at the burners. This heating of the fuel in tanks may be carried out either by steam coils or by electric immersion heaters, whilst the pipes through which the oil flows may be lagged with asbestos rope to minimise the cooling of the oil. Creosote fuels are apt to contain acids, which attack brass and other non-ferrous fittings, and this point must not be overlooked when imported fuel oil is being replaced by creosote fuels.

As a class, liquid fuels possess most of the advantages of the richer gaseous fuels, since the capital cost of furnaces and auxiliaries is low and little other equipment is necessary. High flame and furnace temperatures can easily be obtained, and the fuel, which has a high calorific value, can readily be transported. An additional advantage is that liquid fuel can easily be stored in a comparatively small space. There are no standby losses, which cannot easily be avoided when producer gas or water gas is used. The cost per B.Th.U. with liquid fuels is higher than for gaseous fuels, the fire hazard is increased, and the very high flame temperatures easily reached are liable to damage the furnace structure, and also the steel charge, unless proper care is exercised. If a reducing atmosphere is required in the furnaces, the use of preheated air is necessary, to avoid the production of an excessive amount of smoke. Liquid fuels are used more for reheating stock for forging or drop stamping than for heat-treatment, chiefly because the operation and control of oil-fired furnaces becomes more difficult as the furnace temperature is reduced, especially when heavy oils must be used.

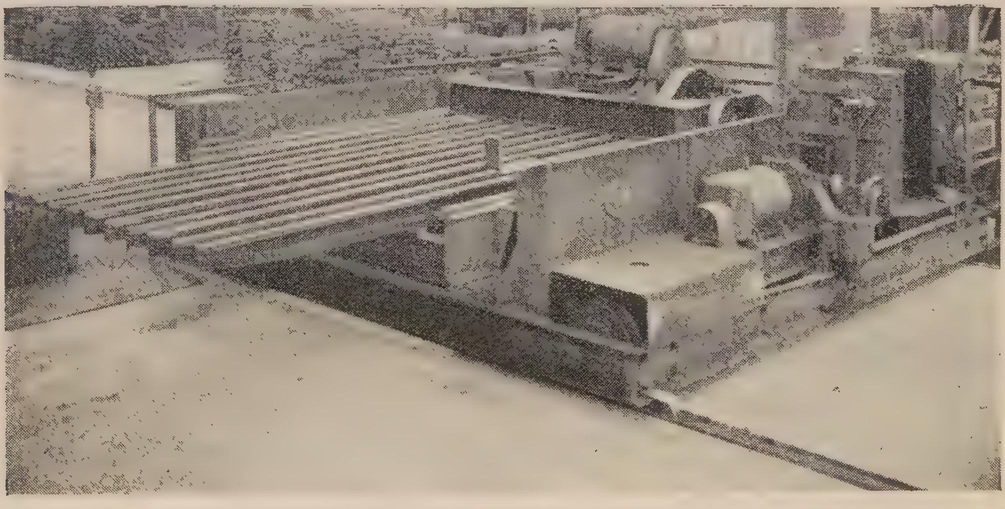

FIG. 4.—ELECTRIC CHARGING MACHINE ON WIDE GAUGE TRACK.

Solid Fuels

Coal itself is the most important industrial fuel, since all the fuels described above, except those derived from petroleum oils, are obtained either directly or indirectly from coal. The term coal covers a wide range of carbonaceous materials differing considerably in almost every respect, their properties, however, having a decisive effect in determining the suitability of a given class of coal for a specific purpose. As a fuel, coal is still the cheapest in prime cost, and where furnacemen are trained to use it properly, it can give excellent service in a variety of furnace installations. Frequently, however, the duties of a furnaceman include many activities other than firing, with the result that firing is done very heavily at infrequent intervals, leading to continual variations in the furnace atmosphere and temperature.

The advantages of coal as a direct fuel are that the costs of fuel, furnace installation and operation are low, whilst storage of the fuel is easy if space and surplus fuel are both available. In wartime it is not, however, always possible to obtain adequate quantities of coal with the properties and size distribution desired, nor is it easy to obtain and retain skilled furnacemen. The necessity to provide facilities for handling coal and ashes is a disadvantage. Unless the furnaces are well designed and operated skilfully, considerable variations occur in furnace temperature and atmosphere, excessive oxidation of the charge results, and there is an increase in the maintenance cost of fireboxes and grates.

One application for which coal is particularly suitable is in the operation of small plants where producer-gas or water-gas installations would be too expensive. Small isolated furnaces can be heated efficiently by an automatic underfeed stoker, of which a number of good types are now available. If suitable fuel be used, these stokers require little attention and give very good control of the furnace temperature.

Coke.—The advantages and disadvantages of coke as a fuel are similar to those of coal. It is, however, more expensive and supplies are sometimes more difficult to ensure. During wartime there is an increased tendency for supplies to vary in successive consignments, owing to changes in the quality and source of the coal supplied to the coke ovens. It cannot produce a smoky black atmosphere, but on the other hand to secure a neutral or reducing atmosphere demands very heavy firing.

Pulverised Fuel.—The heating of furnaces by pulverised fuel is by no means uncommon, but it is used for reheating stock for forging and similar operations rather than for heat-treatment, since it is more suitable for obtaining high furnace temperatures than the medium or comparatively low temperatures used in heat-treatment. The pulverised fuel is usually obtained by crushing coal of singles size, and unless comparatively expensive drying equipment is installed it is difficult to ensure a regular supply of dry powdered coal at the burners, especially during wet weather. This difficulty can be overcome by using a preliminary crusher which is supplied with large coal up to cobbles size, in which the moisture content is always very much lower than in washed singles. In winter, any wagons covered with snow must be allowed to stand in the shop until the snow has melted and the water drained away, before the coal is charged into the crusher. In some districts it is now possible to buy coal ready pulverised and dry, thus eliminating the necessity for installing a pulverising system at the consumer's works.

With pulverised fuel, the control of furnace atmosphere and temperature is much easier than when coal is burned on the grate, though less easy than with gaseous fuels. There are, however, several disadvantages attending the use of pulverised fuel. The flame temperature is high, leading to a high maintenance cost for the combustion chamber, where ash at high temperatures is liable to attack the refractories. The furnaces must be periodically shut down for removal of slag and ashes, whilst the occurrence of layers of ash on the steel charge, and its distribution over the surrounding locality, are sometimes a nuisance. Unless special care is taken there are leakages of coal dust into the shops and this dust, settling on girders, crane motors and in numerous other places, increases the fire hazard and makes it difficult to keep the shops clean. In addition, the use of recuperators or regenerators is not practicable when pulverised fuel is being burned.

Electric heating of heat-treatment furnaces has many advantages. Little auxiliary equipment is necessary, automatic control of furnace temperature is easy, and as the furnace chamber can be kept closed any type of atmosphere can be used, as desired. The labour cost is low, and it is easy to keep the plant and shop clean. No handling facilities are required for fuel, ashes or waste gases. A furnace can be put down anywhere where there is a sufficient supply of electric energy, and can easily be moved from one shop to another if required.

The capital cost of such furnaces and equipment is high, however, and the energy cost per B.Th.U. is also high in this country. Most electric furnaces are slow in reaching a high temperature from the cold, and the energy cost is considerably increased if the furnaces work intermittently. This is partly on account of heat losses and partly on account of the service charge, if the current is taken from a supply company. The cost of heating elements is somewhat high, but if newer types are used, such for example, as the hairpin design, burnt out elements can be replaced without arresting the operation of the furnace.

Choice of Type of Fuel

If a new furnace installation be under consideration, the first point to be determined is the nature of the heating medium. From a consideration of factors such as have been referred to above, some fuels can be eliminated at once. Frequently, the choice of fuel for the new furnaces is obvious when, for example it is merely an extension in the use of a fuel already provided, as may be the case when a new furnace can be served by an existing gas-producer plant. The type of furnace is next decided from a knowledge of the operations to be carried out, and of the facilities available in the shop. The purpose of the heating, such as for annealing, tempering or hardening, with a figure for the maximum temperature to be reached, must be known. Other information required includes the period of the heating cycle, with the length of time each furnace will work each day, and particulars of the material to be heated; for example the range of dimensions including thickness, and number to be heated at one time.

These details, and the method of handling the articles during charging and discharging, influence the selection of size, shape and type of furnace. The provision of recuperators, regenerators, or even of waste-heat boilers, is governed by the circumstances of each particular case.

The facilities available include the floor area and height which can be utilised; the presence and nature of overhead cranes; electric, steam and water supplies, and the space which can be spared for stocking fuel, if this is of a type which can be stored. One factor important in every aspect of the installation is the availability of suitable labour, since, if this is scarce or expensive, it is worth while to increase the capital cost by providing labour-saving mechanisms wherever possible.

When information such as the above has been obtained, the officials responsible for the new plant can approach furnace builders for detailed designs and estimates. Large organisations, with engineering and technical departments, often design their own furnaces, which are then built either by outside contractors or by the company's own building department. Frequently, there is a tendency to duplicate a furnace in some other works, which has proved successful for similar duties, without sufficient allowance being made for the differences in conditions between the two shops, which nearly always exist.

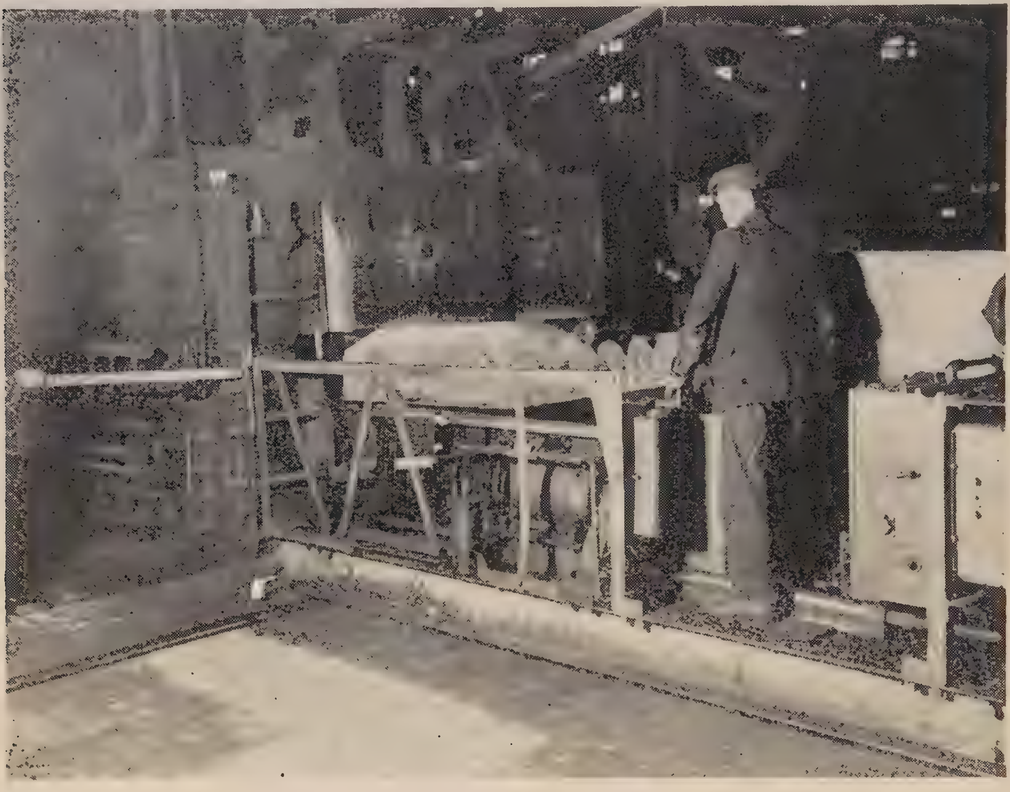

FIG. 5.—CHARGING MACHINE UNLOADING FURNACE.

Heat-Treatment Furnaces

In any discussion of heat-treatment furnaces it is well perhaps to point out that furnaces used for treating steel castings are precisely similar to those used for heat-treating steel articles produced by other processes, such as rolling, forging or drop stamping. Some of the furnaces referred to below are used for the heat-treatment of steel castings, some deal with either forgings or castings according to circumstances, whilst others, used perhaps for drop forgings, could just as easily be used for heat-treating steel castings of suitable size and shape. The processes used in the heat-treatment of steel castings vary with the composition of the steel, and include annealing, normalising, quenching and tempering, but it is not proposed to discuss in the present Paper any aspects of heat-treatment as such.

Very large heat-treatment furnaces are usually heated by raw producer gas. In the main this is due to economic considerations, but is also influenced by the fact that manufacturers of the largest type of steel casting generally have plenty of producer capacity available, and an extensive experience in their operation. For these very large furnaces the fuel cost of town's or coke-oven gas is usually prohibitive. At the same time, for one such furnace in a batch it is worth while considering modifications to enable it to be worked by town's gas as an alternative to raw producer gas. This provision enables the single furnace to be operated when the amount of work to be done is small. It often proves more economical than maintaining the producers in operation, and keeping all the flues full of gas which is almost stationary, and fouls the flues more quickly than when all the furnaces are working.

Such an arrangement is in operation in one of the large steelworks, and is applied to a heat-treatment furnace having a hearth 14½ ft. wide and 40 ft. long. This furnace is equipped with regenerators and is normally fired by producer gas. The change-over to firing by town's gas is simple and takes only a few minutes. When the furnace was first put into commission, some difficulties were experienced owing to the wide difference in calorific value of the two gases, and also owing to the deposition of suspended matter by the producer gas. Whilst the furnace was working on town's gas, tarry matter was deposited at the valves, shutting off the producer gas, causing trouble when, later, it was desired to revert to producer-gas firing. The carrying out of minor modifications, however, quickly removed these difficulties.

If cold, clean producer gas is the normal fuel, the utilisation of town's gas as an alternative is easier, since there is little deposition of suspended matter from either gas, but there are still difficulties owing to the great difference between the calorific values of the two gases. It is comparatively easy, however, to work furnaces on a mixture of clean producer gas and town gas having a calorific value between 300 and 400 B.Th.U. per cub. ft., so long as there is an efficient pressure controller which can be altered according to the calorific value of the gas being used. In such cases it is essential to control accurately the flow of each gas into the mixing length of main, and for this mixing main to be long enough to ensure that the issuing gas is uniform in composition before it reaches any of the furnaces.

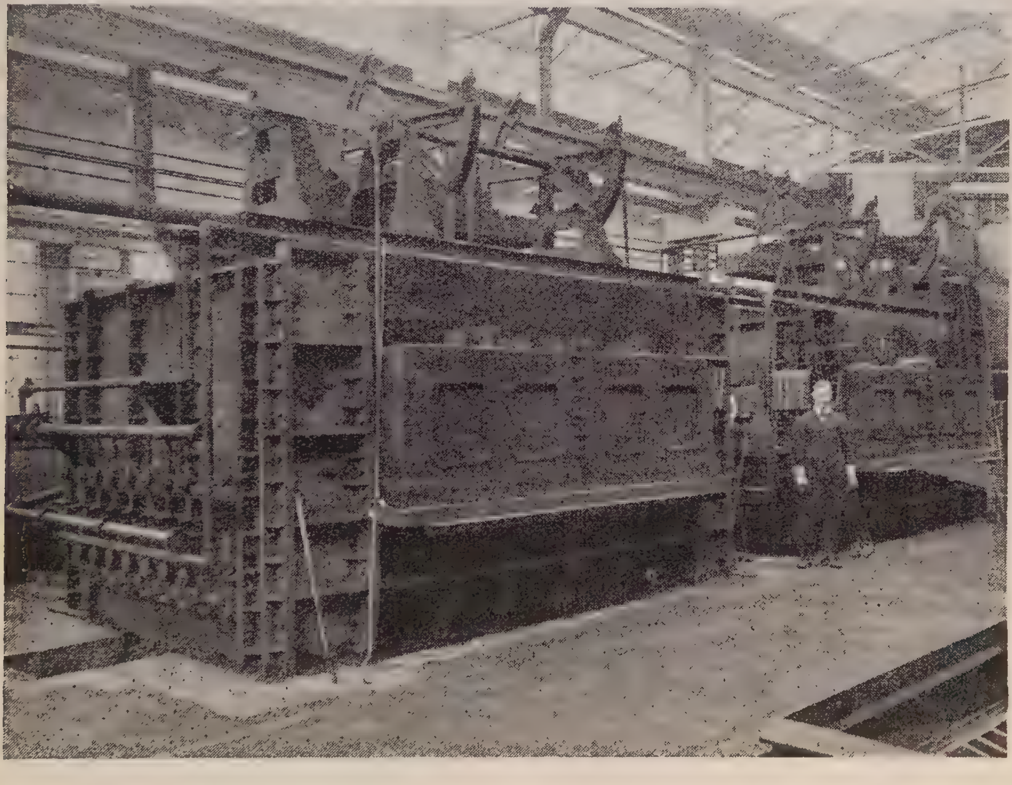

FIG. 6.—TOWN'S GAS FIRED FURNACE BEFORE FITTING COKE PRODUCER.

Batch-Type Regenerative Furnaces

The large furnaces now being considered are nearly always intermittent, or batch-type furnaces, with regenerators below the hearth, and the stock is usually allowed to cool down to a safe temperature in the furnace. The car-bogie type of hearth, which offers the easiest means of handling large castings and forgings, is the type usually adopted. One of these furnaces, fitted with a type of bogie and track which has proved very successful, is illustrated in Fig. 1. The bogie is carried on three rail sections at each side, these resting on grooved rollers, which are always cold, and can be lubricated or serviced conveniently at any time. With large castings it is important to have plenty of free furnace space available, since the rate of heating of the stock is governed by the rate at which heat can be transmitted from the outer layers of the material to the centre. If some part of the stock is near enough to the gas flame for pronounced local heating to occur, then the object of the heat-treatment is defeated.

The transfer of heat by radiation does not begin until a temperature of about 500 deg. C. is reached, and the heating of stock up to 650 to 700 deg. C. is carried out almost entirely by convection. It is thus necessary to pay attention to the circulation of the products of combustion in heat-treatment furnaces, and in this connection an appreciation of the duties of the stack damper is important. Where the heating medium enters the furnace by virtue of its own energy, as in the case of gas, the only function of the stack is to remove the products of combustion from the furnace, and the height of the stack is immaterial. The stack must, however, be carried through the roof and sufficiently high above surrounding buildings to prevent stack gases from blowing down into the shops. This provision makes the stack unnecessarily high from the furnace point of view, and more draft is set up than is required. The stack damper should, therefore, be used intelligently to counteract the excessive draft so as to maintain in the furnace chamber a pressure equal to, or slightly above, that of the outside atmosphere.

Furnaces for Medium Size Stock

For rather smaller stock, which still however requires car bogies for convenience in handling, producer gas is still the most widely used fuel, but town's gas and, to a smaller extent, oil and pulverised fuel, begin to make their appearance. During wartime, however, it is most unlikely that for heat-treatment purposes, oil heating will make further progress. With this type of work efforts are frequently made to speed up the output and at the same time economise in fuel, by eliminating the necessity for allowing the castings to cool down in the heating chamber. These advantages are secured by building the furnace in several sections, each section being separated from its neighbour by a door, and holding one or more car bogies which can be pushed right through the furnace. A typical example of this type is the three-chambered furnace in which the first chamber is used for preheating, the second one for soaking at temperature, and the third one for cooling. Waste gases from the centre chamber are usually used for preheating the castings in the first chamber, but alternatively they may be used in the third chamber to retard the cooling of the castings, if necessary. For castings which are smaller and more or less uniform in size, the number of chambers can be increased to any desired extent until a continuous cycle is reached, occupying a selected number of hours to complete. In such furnaces it is usual for all doors to be interconnected so that they are all lifted at the same time, to allow the movement of the bogies.

Heat-Treating Small Components

As the size of furnace is further reduced, the utilisation of continuous-operating mechanisms becomes easier, and both town's gas and electricity are more extensively used as the heating medium. The stock is lighter in weight and thinner in section, so that the heat reaches the centre of the stock more rapidly, and larger throughputs can be obtained. Mechanised furnaces in this range have made rapid progress during the last few years, fitted with a variety of equipment, including pusher types, chain conveyors, rocker bar and walking beam conveyors, helical or monorail conveyors, and many others. Each type has its own advantages, but it is not proposed to discuss these in the present Paper. The increasing application of such mechanisms to obtain rapid, effective, and consistent heat-treatment is partly due to the production of new and more efficient heat-resisting steels.

The continuous furnace is not superseding the batch type completely, since one of the most popular types of furnace, even for small work, is a batch type with an adjacent cooling chamber. In this type, which may be heated by means of town's gas or electricity, the stock is loaded on to trays, and after heating the completed trays are pushed through the back of the furnace into a cooling chamber, which is separated from the main furnace chamber by a gas-tight door. The heating chamber is then recharged and the cooled trays withdrawn after the appropriate cooling period. Alternatively, an arrangement may be fitted for dropping the castings into a quenching tank directly from the cooling chamber, so that there is no opportunity for the castings to cool, and they do not come into contact with the outside air for an appreciable length of time.

A simple example of such a furnace with one chamber only is illustrated in Fig. 2. This furnace is fired by town's gas, and immediately in front of it is a quenching tank which may contain either water or oil. In the illustration, the furnace is being loaded with wheel centres. An inclined apron is fitted to the front of the furnace, and when the castings are ready each is pulled forward in turn until it falls down the apron into the tank. A similar furnace is seen alongside with the apron supported in a horizontal position, which is frequently convenient for charging purposes.

In works with a large regular output of small to medium weight castings or forgings, excellent results may be secured from a battery of heat-treatment furnaces with charging and discharging equipment which serves all the furnaces. An example is illustrated in Figs. 3, 4 and 5. The battery of furnaces concerned is heated by town's gas, the temperature being controlled automatically. As seen in Fig. 3, the furnace hearth is formed as a series of piers running the whole length of the furnace. A charging and discharging machine, illustrated in Fig. 4, runs on a wide-gauge track in front of the row of furnaces, and carries a series of prongs which can be extended into any furnace, and fit in between the piers, thus enabling stock to be charged or withdrawn. Fig. 5 shows the charger withdrawing the stock from a furnace. Between the furnaces are quenching tanks, and the stock withdrawn from the furnaces can be placed in trays, which are then lowered below the surface of the oil.

Similar equipment in a variety of designs is now in use in many works, serving batteries of furnaces heated either by town's gas or by electricity, both of which lend themselves to accurate temperature control and the performance of very regular time cycles in heat treatment.

Semi-Portable Producers

The advisability of being able to replace town's gas by some other gas at short notice has already been mentioned. One method of ensuring this is to use small semi-portable producers burning coke as a fuel, giving clean coke-producer gas which does not readily clog the pipes or burners normally carrying the town's gas.

Several types of such producers are now being manufactured, the cross section of one type being illustrated in Fig. 7. This producer is a modification of one developed by Mr. A. G. Hales, of the Coal Utilisation Research Association, for use in propelling vehicles.

Two of these producers have been installed to heat a furnace of the type shown in Fig. 6, having two rows of eight town's gas burners, one along each side of the furnace.

Referring to Fig. 7, the producer consists of a hopper (1) at the base of which is attached a fuel-feeding cone (2), which also forms the gas outlet (15). This cone allows the fuel to flow through an annular gap between it and the producer wall, thereby causing segregation of the fuel to take place, so that the smaller fuel remains at the side of the producer and forms a protective layer, whilst the larger fuel flows towards the centre and ensures a path of low resistance for the combustion gases. A poking hole (3) is provided at the base of the hopper.

The producer proper consists of a double-walled chamber, lined inside with fireclay cement (4), at the base of which is a heat-resisting iron ring (6). Below this ring is an ashpit (9) with an adjustable sleeve (10) to facilitate the removal of ashes at the end of a run. The iron plate (12), which supports the fuel bed, has four radial ribs on its upper surface, and when the plate is rotated by means of the external handle (13), these ribs crush the ashes against the fixed blades (11), thereby making it possible to remove all the ashes through the ash door (14).

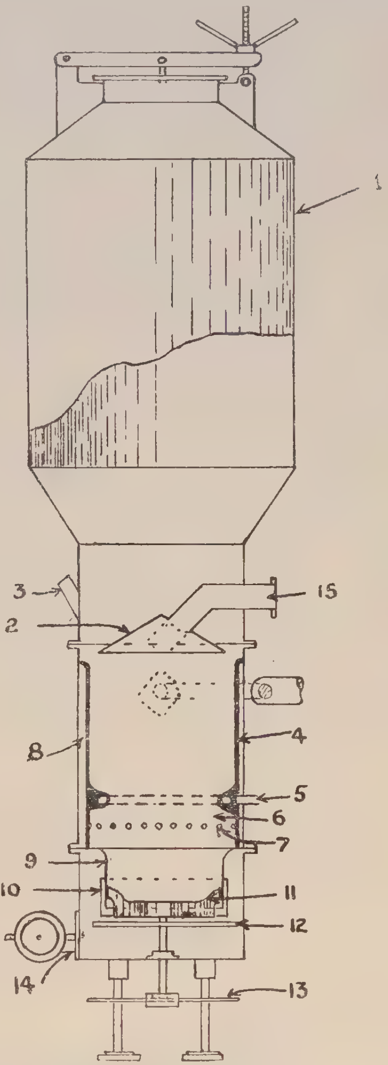

FIG. 7.—MODIFIED C.U.R.A. PRODUCER.

The preheated blast enters the peripheral jacket (8), and passes through holes (7) drilled in the ring (6) to the gas chamber proper. A water-cooled ring (5) is situated just above the holes at the point of highest temperature.

The complete equipment for one producer is shown diagrammatically in Fig. 8. An electrically-driven booster provides air under pressure for the blast. The pressure and quantity of air supplied are regulated by the air by-pass, which provides a bleeder for any excess air. The blast air is heated in the preheater, through which the producer gas passes on its way from the producer. The steam for the blast enters the preheater as water, is vaporised, and the steam mixed with the incoming air. The air and steam enter the producer, pass through the fuel bed, and the producer gas is carried through the preheater to a dust separator, where any fine particles of coke or ash are arrested, so that clean gas passes on to the furnace. Gauges are fitted to the blast pipe and delivery pipe so that the blast pressure and gas pressure can be observed.

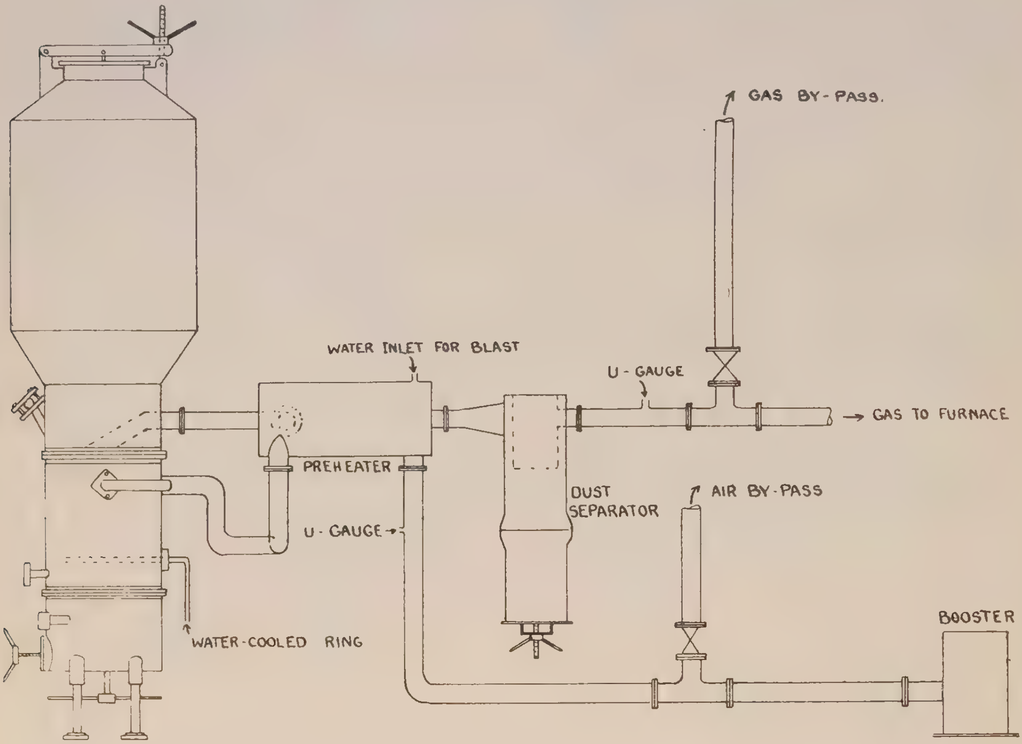

FIG. 8.—DIAGRAMMATIC ARRANGEMENT OF PRODUCER AND ACCESSORIES.

In starting up, an oxy-acetylene or similar burner is placed in the coke hole (3), the blast turned on, and the gas by-pass opened so that the gases escape to atmosphere until the producer is in full operation. This gas by-pass should be carried outside the shop so that the shop atmosphere is not contaminated with carbon monoxide. As soon as good gas is being obtained the gas by-pass is closed, and the producer gas lighted at the burners.

The following has been found to be the approximate range of chemical analysis and calorific value of the gas:—Carbon monoxide, 28 to 32 per cent.; hydrogen, 8 to 12 per cent.; carbon dioxide, 2 to 5 per cent.; oxygen, 0 to 0.5 per cent.; nitrogen, 52 to 58 per cent.; calorific value, 140 to 150 B.Th.U. per cub. ft. Since the producers are alongside the furnace, the gas contains some sensible heat which is not included in the above calorific value.

The quantity of gas and to some extent the quality depend on the conditions of operation, but an approximate figure for a producer of 20 in. dia. would be an hourly output of four therms, equivalent to about 2,700 cub. ft. per hr. of gas at an assumed average calorific value of 145 B.Th.U. per cub. ft. The normal heat consumption of a furnace when using town's gas can be calculated from the calorific value and the volume used per hour, and to replace it by coke-producer gas requires approximately the same total heat value in the producer gas. As the calorific value of the producer gas is less than one-third that of town gas, the volume of producer gas supplied to the furnace must be increased accordingly, so that the gas pressure required is substantially greater than when town's gas is being supplied.

The gas burners must be examined to make sure that there are no local constrictions which would interfere with the passage of the increased amount of producer gas at the higher pressure. The amount of air required for complete combustion by producer gas is much less than that required by the same volume of town's gas, and burners must be adjusted accordingly, but this operation is usually very easy.

The operation of these producers is influenced considerably by the quality and size of the coke, and to obtain the best results a graded coke must be used, such as one containing only pieces between $\frac{1}{8}$ in. and $1\frac{1}{8}$ in. in size.

From the above brief survey, it may be concluded that during recent years the design of heat-treatment furnaces and their associated equipment has made considerable progress, particularly in furnaces intended for the heat-treatment of small or medium weight castings and similar articles. There is a reasonably wide choice of fuels, even in wartime, and the total cessation of work if the fuel normally used becomes unavailable can be avoided by intelligent anticipation. The importance of heat-treatment as a process in the manufacture of steel castings is being realised by an increasing number of foundries, especially where new specification requirements must be met. Whilst the object of heat-treatment is to put a casting into the physical condition required, the cost of the operation must not be overlooked. This is greatly influenced by the intelligence shown in the planning of the operations, and subsequently by the skill of the furnace operators. Devices such as are employed for controlling furnace atmospheres and temperatures are extremely useful, especially when they are maintained in proper working order, but there is sometimes a tendency to rely on them too much, both by the management and by the furnace operators.

The authors wish to thank the Directors of the English Steel Corporation, Limited, for permission to publish this Paper, which is largely based on experience obtained in the various works of the Corporation.

DISCUSSION

EAST MIDLANDS BRANCH

The discussion was opened by MR. S. LEWIS, who said that he could not agree with Mr. Smith that the drying of coal for pulverising was expensive if handled properly. In the heat-treatment of malleable castings within boxes he used pulverised fuel extensively, both from unit systems and central bin and feeder systems without expensive drying. Mr. Smith did not consider pulverised fuel the cheapest method of firing his furnaces. Did he use fuel oil and town's gas because he found it the most effective method of doing his particular job? Mr. Smith advocated preheating his air. Did he think this is an advantage when using town's gas?

High Maintenance Costs

MR. SMITH, replying, said that he had not stressed the expense attached to the drying of coal for pulverising quite so much as Mr. Lewis had indicated. For some reason or other the plant referred to had been installed without a preliminary raw coal drier and they very soon ran into trouble on this account. As pointed out in the Paper they had overcome the difficulty by installing a preliminary crusher, thus enabling larger coal to be fed to the plant. By this means the amount of surface water being fed into the plant was reduced by over 70 per cent. The cost of the crusher was £200 and little or no alteration to the existing coal handling equipment had been necessary; furthermore, the plant had never been shut down to enable the extension to be carried out. If the problem had been overcome by installing a drier then the initial cost of the drier would have been several thousand pounds and fairly extensive alterations to the coal handling plant would have been necessary. Firing by pulverised fuel was undoubtedly cheap, but when maintenance expenses to furnaces were taken into account over a long period then many of its advantages disappeared. He preferred to use town's gas for heating for the reasons set down in the Paper, and that preheating the air was naturally advocated in the interests of fuel economy.

MR. K. DOCKSEY said that Mr. Smith had given a very good description of the various fuels and furnaces for the heat-treatment of steel castings. He would like to know the comparative cost of town's gas, producer gas, pulverised fuel and liquid fuel when operating an annealing furnace, say, from 8 to 10 hrs. per day? He had operated oil-fired and coal-fired annealing furnaces with success and found coal-fired furnaces to be cheaper in fuel costs.

MR. SMITH replied that he had no actual figures available but the order of heating costs for the fuels mentioned would probably be town's gas, liquid fuel, producer gas, pulverised fuel, the latter two fuels being the cheapest.

Effect of Ash on Refractories

MR. JENNINGS (visitor) remarked that the Paper covered an extremely wide subject, and that the authors were to be congratulated on making it so comprehensive. He commented that the figure for the calorific value of town's gas quoted at 500 to 550 B.Th.U. per cub. ft. appeared to be rather high for standard practice. Dealing with the section devoted to raw producer gas, he realised that if the fine particles of tar were allowed to enter the combustion chamber, the calorific value of the fuel would obviously be raised, but could the author enlighten him as to the effect of the ash so formed corroding the furnace refractory interior, and whether this had any effect in spalling these refractories?

The authors had remarked that to obtain the best results on these producers, the size of coal must be between fairly definite limits, and the coal must not swell too much on heating. Mr. Jennings remarked that in wartime the choice of coals for gas-making was very limited and that firms using coal for gas-making purposes were obliged to use the type of coal allocated to them. It was, therefore, difficult to obtain coal with a constant swelling number.

Disadvantages of Liquid Fuel

In connection with liquid fuels, Mr. Jennings was surprised that, having regard to all disadvantages, combined with the present high cost, any firm would be prepared to instal new oil-fired plant. Having had a certain amount of experience with creosote B pitch in open-hearth melting furnaces, the point which struck him was the large amount of "fly" ash which was present, and which made a filthy mess of the shop. In considering the cost of this fuel, it was necessary to bear in mind that some heating means, such as steam chasers, are necessary to keep the fuel fluid in the pipes, especially in large installations, and that the cost of this steam was no small matter. A further disadvantage with oil fuel which the authors had not mentioned was that the fuel had to be atomised by means of high-pressure air on a special burner, and this required the provision of fans with the consequent maintenance and risk of breakdowns.

In passing, when Mr. Smith mentioned electric heat-treatment furnaces, he made a point that, as the furnace chamber could be kept closed, any type of atmosphere could be used as desired. Mr. Jennings queried this point, and doubted whether any electric furnace could give any atmosphere control whatsoever without the provision of certain purge gases.

Stand-by Producers

With regard to the stand-by type of producer illustrated, it was queried whether, in view of the extremely fine tempering temperatures which have to be maintained to-day in order that the desired physical specifications may be obtained, from modern alloy steels, whether standby producers could be operated satisfactorily. With some of these steels it was essential to temper with + or − 5 deg. C., and with the varying fuel input of the furnaces, they would need constant correction and control. Mr. Smith had admitted that these producers were intermittent in operation, and it was Mr. Jennings' experience that the calorific value of the gas being supplied from such producer varied with the length of time which the producer had been working, since it was last clinkered and charged. It was possible to maintain a constant pressure at the furnace, but if the calorific value was variable, it would not be possible to incorporate automatic controls as far as he was aware.

Overcoming Spalling

Replying, MR. SMITH said that, as Mr. Jennings was no doubt well aware, each gas undertaking fixed its own calorific value, which had to be rigidly adhered to. The range of calorific value of all undertakings in Great Britain was from 400 to 600 B.Th.U. per cub. ft., a good average being 500. He was rather surprised at Mr. Jennings' second question, for he, himself, attributed any erosion difficulties to the entrained dust from the producer fuel rather than to the ash from the tar. In any case, owing to the generally low velocity of the gases in a producer-gas-fired furnace, he would not be too hasty in blaming dust erosion for the spalling of refractories and would consider it best first to decide if the most suitable refractories were being used.

Swelling Coals

Regarding the question on swelling coals, he stated that coals having a swelling number greater than 3 (B.S. Crucible Swelling Test) created a great amount of trouble in static gas producers, but coals up to swelling number 5 could be handled in modern gas machines, but it was always better to mix with them a weaker swelling coal. The problem was not caused by the absence of weakly swelling coals, but rather by the enforced use of coals which normally would be ruled out on account of high ash, sulphur, etc., or low fusion point of the ash. The installation of oil-fired equipment in some localities was a necessity for many gas undertakings were now working to capacity. In the case mentioned the object was to provide means for switching over to an alternative fuel in the event of gas supply being interrupted because of enemy action.

"Fly" Ash

Referring to troubles due to "fly" ash in liquid fuels, he must assume that the furnaces could not have been fitted with a waste gas flue for such troubles to occur, even so one would not expect too much dirt. The ash content of a sample of creosote B pitch recently tested in the authors' laboratory was only 0.089 per cent. Mr. Jennings was, of course, quite correct in his statement about pre-heating the oil.

It appeared to him that the point about fan maintenance, etc., had been rather over-stated, for it could hardly be any worse than for other types of furnaces which used forced draft. Mr. Jennings in his remarks on electrically-heated furnaces had stated exactly what the authors had in mind when he referred to purge gases. The advantage, of course, lay in the fact that such gases could be constantly recirculated and were not subject to changes in composition due to dilution by the heating medium.

In reply to the question on stand-by producers, the furnace temperature could be very easily controlled by simply increasing or decreasing the air-blast pressure as required. This also covered the point about fluctuating heating value. Since the producers were only intended as stand-by it would not seem necessary to design automatic control, but speaking off-hand he thought that it would not be impossible to have the air valve worked in conjunction with the furnace temperature.

Fire Hazards from Pulverised Fuel

MR. S. SPRAY said he would like to know the maximum swelling number advised for static producer coals. Was the risk of spontaneous combustion of pulverised fuel much less with anthracite than with bituminous coal? If so, would the danger point still be a bin temperature of 150 deg. F., as indicated by Mr. Smith in his remarks?

MR. SMITH replied that his experience indicated that if one used a coal of swelling number 4 then trouble was likely to occur; if the swelling number could be kept down to 2, so much the better; if it got as high as 5 then the furnaces were almost certain to be short of gas, unless, of course, the producer plant was working under capacity. If swelling coals must be used then it was imperative to persuade the gas operators to feed little and often, in other words to try and approach automatic feeding conditions.

The risk of spontaneous combustion with anthracite was quite remote in comparison with ordinary bituminous coals, but if fire equipment, on the lines indicated, was installed the "danger" temperature could still be taken as 150 deg. F.

MR. T. GOODWIN said from the Paper and discussion it was apparent that Mr. Smith had a definite leaning for producer gas or town's gas, yet the Paper said that coal was the most important industrial fuel. Coming to pulverised fuel he noted that the authors stressed the dust problem in relation to dirty shops and fire hazards; surely, when one put in a pulverised fuel plant that was the first thing attended to. The authors stated that the use of recuperators or regenerators was not practicable when pulverised fuel was being burned. He would like to know why?

The Dust Problem

MR. SMITH replied that coal was certainly the most important fuel, but the present discussion was related to the problem of using the available heat units in the most economical and efficient manner; in other words, to decide whether the coal was best burned directly or in two stages. Referring to dust problems, one could make any preparations one liked, but the dust problem would invariably arise either from the pulverising plant itself or from the furnaces.

Their statement regarding heat recovery was not intended to convey the impression that heat recovery was impossible with pulverised fuel. It certainly was not, but it was not practicable to apply it on quite the same scientific basis as was possible with gaseous fuels. If he could be accused of having a definite leaning towards gaseous firing he thought that sufficient reasons had been stated in the Paper to justify that leaning.

MR. C. D. POLLARD said he would like to ask him to express to Mr. Walker their thanks and appreciation for his share in the preparation of the Paper. In the published Paper there was an illustration of a town's gas-fired furnace with a pier hearth. He would like Mr. Smith to tell him whether with town's gas furnaces it was definitely necessary and essential for the furnace to have a pier hearth as the one in the illustration.

MR. SMITH replied that it was definitely not necessary to have a pier hearth with town's gas furnaces.

Vote of Thanks

MR. J. ROXBURGH said some might not appreciate to the full the technicalities of this Paper, but a survey, such as was contained in this Paper, was extremely useful at any time and particularly so during this wartime period. The authors had referred to what they term "intelligent anticipation," which of course was a quality possessed by any good management, and undoubtedly during this war executives have realised that certain materials would become unavailable and naturally it was much better to become aware of such a possibility beforehand, and meantime explore the possibilities of substitute materials than to lack "intelligent anticipation," and suffer in consequence. This question to which the authors have given prominence should be a useful reminder. Mr. Smith has dealt adequately with the Paper and the discussion, and he (the speaker) had therefore very great pleasure in proposing that a hearty vote of thanks be accorded to the joint authors of the Paper.

The motion was seconded by Mr. Goodwin and a suitable reply by Mr. Smith ended the meeting.

WRITTEN COMMUNICATION

Mr. C. Webb wrote:—The Paper is a very valuable contribution to the literature already available on the selection of fuels for industrial furnaces, the principal points for and against each fuel being clearly given. Similarly, the section on furnace types is very useful, and should be of considerable assistance to the potential user in that it will help him to form a clear view of his requirements when discussing the proposed installation with the furnace builder.

In regard to the question of the large and medium sized heat-treatment furnaces fired with raw producer gas, emphasis is laid on the use of reversing regenerators as opposed to recuperators, the latter it is claimed being easily choked up. There are, however, a number of recuperators available both of the refractory and metallic types which give entirely satisfactory results in practice, and will hold their efficiency over a number of years without any attention. The deposit which occurs in the waste gas flues of recuperators is usually fine ash carried over with the products of combustion, which is readily disturbed, and particles of scale from the charge. Provided that means are included for periodic cleaning of the waste gas flues, little trouble is experienced. In the modern type of recuperator of either the refractory or metallic type, leakage is reduced to a minimum.

Advantages of Recuperators

Some of the advantages which can be claimed for recuperators are as follows:—

(*a*) Considerably less space occupied; hence less excavation and foundations and, therefore, less capital cost.

(*b*) As the flow of the products of combustion and of the air is always in the same direction through the recuperators, there is no necessity to compromise in the design of the burner and exhaust ports in the furnace, and each can be arranged for its own specific purpose. The result of this is that improved combustion conditions are obtained in the furnace; also control of the furnace atmosphere is more readily obtained. It is moreover possible to use metallic burners of scientific design even for raw producer gas, which always show advantages in control when compared with ordinary brick ports.

(*c*) Recuperators generally, and particularly metallic types, have a lower heat storage capacity and, therefore, the air for combustion is more quickly brought up to temperature. This is of particular value in furnaces for intermittent operation, and for those in which a heating and cooling cycle has to be performed in the furnace.

Quite high temperatures of air preheat are possible with refractory recuperators, and in fact this type of recuperator is being used extensively with such high temperature furnaces as soaking pits, heating furnaces for heavy forgings, and glass melting furnaces. Many such furnaces fired with hot raw producer gas, fitted with refractory recuperators and precision type metallic burners, are provided with automatic control equipment, which closely approaches in efficiency that obtained with cleaned gases of high or low calorific value.

AUTHORS' REPLY

In reply to Mr. Webb, the AUTHORS wrote:—

We are indebted to Mr. Webb for this thoughtful contribution, and regret that considerations of space precluded a more complete description of all the modern variations of furnace types.

It is, of course, true that furnace design has advanced considerably during the last few years, and this applies especially to new forms of furnaces incorporating recuperators. Ever since their introduction over 80 years ago, regenerators have been highly popular where high temperatures were required, and the furnaces were large or medium in capacity, but lately the recuperator has challenged this position in furnaces of gradually increasing size.

Furnaces fitted with either regenerators or recuperators naturally work best when the passages are properly cleaned out at frequent enough intervals. We have found that, owing to the stress of wartime conditions, such cleaning is apt to be postponed or hurriedly and incompletely done. The consequent reduction in efficiency is, from our experience, liable to be greater with both regenerators and recuperators of the tubular type than with the older form of regenerator chamber filled with checker bricks, though this, of course, is no fault of the designer of the modern type of furnace.

Where large furnaces are used for the heat-treatment of very large articles, either castings or forgings, the heat-treatment cycle is comparatively long. After a furnace has been shut down to allow the charge to cool, or to be withdrawn, the high heat capacity of large regenerator chambers is advantageous in facilitating the relighting of the furnace for the next heat cycle. In small furnaces, where the cycle of operations must be much more rapid if satisfactory outputs are to be obtained, this high storage of heat is undesirable and small regenerators or, in many cases, a recuperator with its still smaller heat capacity, are much more suitable.

Mr. Webb's remarks emphasise the necessity for careful consideration of the types of furnace available before any new furnaces are installed. A modern furnace of high efficiency can be designed for practically any heating process or treatment cycle, but it is essential for the furnace designer and builder to be supplied with the fullest information regarding the duty expected of the furnace and the operating facilities available, if the best results are to be obtained.

East Midlands and Lancashire Branches **Paper No. 758**

The Manufacture of Malleable Castings by the Whiteheart Process*

By A. E. DAVIES

The object of this Paper is to give a concise and comprehensive description of the various operations necessary for the manufacture of malleable castings by the whiteheart process, mainly on the lines of a comparison with the manufacture of common iron castings, particularly with regard to the moulding operations.

Good malleable castings are a very dependable product, and during these days of war effort many articles which were previously made as steel forgings or steel castings have been replaced by malleable castings. In certain cases this in no way impairs the dependability of the finished product, but it would not be correct to say that malleable castings were as good as, or as dependable as, the best steel forgings or castings. In recent years very much progress has been made in the direction of improvement and uniformity of quality.

Unlike grey iron castings, the manufacturer of malleable castings has a process of manufacture to deal with, before he comes to the varied foundry problems with which the ironfoundry manager is only too familiar. But by strict adherence to good foundry practice, correct mixing of metals to suit the various sections of castings, and careful control of subsequent heat-treatment operations, comparatively trouble-free foundry practice can generally be realised.

Malleable castings are rather more difficult to make than common iron castings, chiefly by reason of the larger contraction and greater shrinkage of the metal, and also on account of the excessive brittleness of the casting in the unannealed condition, but the difficulties do not present much trouble if the usual methods at one's disposal are applied in the proper manner.

Metal Mixing and Furnaces

The first essential to the manufacture of good malleable castings is metal mixing, and if this is laboratory controlled, so much the better; but if the analysis of the metal is not correct in the first place, no amount of good foundry practice will make it so. Hematite irons are the base of these mixtures, and they are available in various qualities. A few years ago manufacturers of malleable castings used almost exclusively a refined hematite mixed only with returned unannealed scrap from the foundry. Steel scrap, if used at all, was used only very sparingly, but to-day many manufacturers are using hematite iron direct from the blast furnace and mixing it with good-quality steel scrap of suitable size, often in proportions up to 50 per cent., together with returned unannealed foundry scrap, and also returned malleable scrap.

Broken ingot moulds, a source of material available at all steel-melting works, may be used in place of hematite iron, but these days the price of this material is very much the same as that of hematite, and the advantage in price is only available to those manufacturers whose works are near to a steel-melting plant. The writer used this material successfully as far back as 1922; it was then not generally known that broken ingot moulds made a splendid substitute for hematite iron, but quite a good run was obtained on this material until the demand forced up prices.

The metal mixture is melted in much the same way as would be the case with common iron castings, using the cupola, open-hearth furnace, pit furnace, or, what is becoming more popular to-day, the rotary furnace (this furnace, of which there are many types, has decided advantages over all other methods of melting malleable iron mixtures). The furnaces are heated in various ways, using gas, pulverised coal, fuel oil, etc., but in all cases the great advantage when using the rotary furnace is the ease with which various metal mixtures can be adapted to suit varying sections of castings. This is one of the most important points in the manufacture of good malleable castings, since a metal mixture that will admirably suit a casting having an average section of, say, $\frac{1}{8}$ in., would be totally unsuitable for a casting having an average section of 2 in.

Another great advantage of the rotary furnace is the perfect mixing and temperature control which is derived from its use, and which are very vital factors from the standpoint of uniformity of grading. Many methods and modifications of melting are in use by various manufacturers with this type of furnace to get continuity of metal supply, with an analysis best suited to the particular section of casting being made, but they are much too numerous and involved to survey adequately in this short Paper.

Functions of Silicon

Silicon plays a very important part in all malleable mixtures, for it is this constituent which chiefly controls the form in which the carbon will be present in the unannealed casting, a factor which is perhaps of paramount importance. Silicon greatly assists the foundry manager from the moulding and casting point of view, but excesses should be avoided, since the higher the silicon content of the mixture, the greater will be the tendency of the carbon present to be precipitated during the cooling of the hard casting; also the presence of graphitic carbon in the structure of the hard casting is absolutely fatal.

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* A Paper circulated to all members of the Institute and read before Meetings of the East Midlands and Lancashire Branches.

Silicon additions alone do not assist in the removal of carbon during annealing, but the ideal mixture is one in which a satisfactory combination of silicon, carbon, sulphur and manganese are balanced in such a way that the silicon is not too high, and the carbon low enough to ensure that all the carbon present in the charge will be in the combined form—that is, as ferric carbide which is visible under the microscope as cementite and pearlite—and not in the free state as graphite. Excess of sulphur does not favour graphitisation, and a mixture with relatively higher silicon and sulphur will give a graphite-free structure in the hard casting.

Manganese neutralises the effect of sulphur by the formation of manganese sulphide, and retards the removal of ferric carbide during annealing, and excesses should be avoided.

Most hematites can be bought to-day with guaranteed analyses, and it is desirable to buy irons with an analysis, particularly of silicon, carbon, sulphur and manganese, to ensure that the resulting mixture will give a perfectly white fracture, especially in the thickest part of the casting, and at the same time provide a mixture the carbon of which is not too stable to require excessive annealing to bring about its malleability.

Silicon considerably helps the fluidity of the metal, and this is a fortunate circumstance, particularly to the manufacturer of thin malleable castings; small sections of, say, $\frac{1}{16}$ in., which are very difficult to cast economically in the foundry, can be cast quite easily and safely with a mixture of considerably in excess of 1 per cent. of silicon.

Silicon additions, however, cannot be taken advantage of to the full from the fluidity of the metal point of view, unless great care is exercised in carefully balancing those elements which retard graphitisation. For, as stated earlier, silicon produces conditions which favour the precipitation of graphite, and the presence of silicon in excess does not improve the characteristics of malleable castings.

Composition of Mixtures

No definite percentage of any element can be given as a basic value, since the effect of any element depends on a variety of conditions and foundry practice, casting temperature, etc. Generally speaking, the silicon content of the metal mixture varies between 0.4 per cent. silicon for heavy castings up to and in excess of 1 per cent. for very light castings.

The writer has conducted various experiments with varying metal mixtures, with extraordinary results, using combinations of silicon, carbon and sulphur. Some very good results were had from freak mixtures containing up to 0.8 per cent. of sulphur, with a relatively high silicon of 1.2 per cent., which is very extravagant, certainly as far as sulphur is concerned. All this goes to prove the necessity of balancing the mixture from the standpoint of the stability of the iron carbide contained in the mixture. The stabilising of the carbon, by introducing excess of sulphur, is particularly evident in this experiment, and the author believes that a complete research in this direction would provide some astounding results.

The general practice, however, is for the sulphur content to be fairly low, about 0.1 to 0.2 per cent., and a manganese of twice that amount (0.2 to 0.4 per cent.), which allows a fairly good margin of silicon to provide a good fluid iron at normal melting temperatures, with freedom from graphite, in the unannealed casting.

The percentage of carbon in the mixture is perhaps taken less into account than any of the other elements; yet it plays the most important part. It is the part removal and breaking down of this element during annealing that converts the hard and brittle casting into the soft and malleable casting. The presence of carbon in the unannealed mixtures is absolutely necessary, although it has to be removed during annealing.

Without carbon the melting point of the mixture would be so high that it would not be practicable to melt it in the same way as the normal mixtures. Carbon gives the metal great fluidity, and, if it is not present in very great excess, does not give rise to excessive annealing. As stated earlier, it should be low enough to ensure that no graphite is present in the structure, as this precipitated graphite cannot be easily removed; in fact, if it is removed, it leaves cavities and spaces in the metal, which give rise to mechanical faults. If care is taken to ensure a safe margin on the ferric carbide side, very little trouble will be experienced.

Moulding and Casting

The moulding and casting of the molten mixture is brought about in much the same manner as would be the case with ordinary common iron castings; perhaps greater care is taken to avoid oxide skimmings from entering the mould. These oxide skimmings appear to be more abundant on the surface of the molten metal than would be found with common iron castings, but they are easily prevented from entering the casting proper if the usual method of taking the gate from the bottom of the main runner is adopted.

Spinning gates are used frequently, and because the metal has a high shrinkage, larger feeding heads will be required. Even very small castings weighing less than 1 oz. will require to be studied from the standpoint of where the gate should be. In general practice, with these small castings, it will often be an advantage to arrange the gate in the thickest part of the casting, or that part that will be the last to solidify, incorporating in the gate a small feeding head proportional to the amount of feeding that will be required.

Large castings will often require several feeding heads, in which case it is not necessary to place the gate in the thickest part of the casting; in fact, it is often an advantage, when using several feeding heads, to gate the casting in the thinnest part, or that part of the casting that is expected to solidify first, and to pour the mould until the metal has completely filled the casting and also about one-third of the feeding heads. Pouring is then halted until the metal in the gate has solidified; the feeding heads are then filled up to the top with hot metal, and the feeding left to take care of itself.

This method will be found to provide perfectly sound castings, except in the most obstinate cases, when the foundry manager has to resort to the use of denseners or chills, which are very popular in the malleable foundry, particularly when high-duty castings are required, or when the castings have to be routine tensile tested, which is often the case with malleable castings.

Care should be exercised when using a chill on a particular part of the casting to see that that part of the casting is well fed, as the chilled part of the casting will be made sound at the expense of another part of the casting; careful combination of chills and feeding heads will be found to deal effectively with the most obstinate case of unsoundness.

Unlike common iron castings, chills do not cause any inconvenience, since obviously all malleable castings have to be heat-treated.

The quick cooling brought about by chills will often be found to improve the mechanical properties of the material, apart from making the casting more sound, and this is particularly evident with the bend test. Over-chilling should be avoided, since this causes weakness; test bars, for instance, cast completely in chills have very poor mechanical properties.

The finished hard or unannealed casting is cleaned in much the same way as common iron castings, always remembering that the castings are very brittle and will require very careful handling. Shot-blasting is more popular than barrelling; all sand must be completely removed from the castings before annealing. Any sand left on the casting will become fused on to the castings during the subsequent annealing process, with disastrous results to cutting tools if the castings have to be machined.

This complete removal of the sand is also particularly important if the malleable castings have to be galvanised, tinned, or electro-plated. It is practically impossible to obtain a good coating if the hard castings are not completely cleaned of all sand before annealing.

Normalising and Cracking

By reason of the fact that the casting in the annealed condition is very brittle, precautions have to be taken to prevent certain types of castings from cracking or breaking during cooling; this is only necessary with medium or large castings, and becomes almost essential when the castings have numerous varying sections, or the castings are of such a shape that they do not cool uniformly.

The high contraction of the metal, together with the unequal cooling of the various sections, causes great stresses and strains to be set up, and the metal, not having sufficient elasticity, ruptures if the castings are not normalised. The breaking or cracking of the castings at this stage is not a fixed rule; sometimes it happens that these stresses and strains are not sufficient to break the casting during cooling; often the castings will not fracture until additional stresses are put on the material during heating up for the subsequent annealing operation, and if normalising has not taken place this causes a very serious loss to the foundry.

In all cases where cracking is likely to happen the castings have to be normalised; this preliminary short heat treatment, apart from relieving all stresses and strains, slightly toughens the metal.

The types of casting that it is thought necessary to normalise are taken from the sand as soon as the metal has set sufficiently to permit their removal with safety, and transferred as quickly and as hot as it is possible into a normalising furnace. This furnace is generally situated very near the parts of the foundry where this type of casting is made. They are heat-treated at a temperature of 850 deg. C. for about 8 hrs., and allowed to cool slowly in the furnace, when they are taken out; they should be cool enough to handle easily.

Normalising will prevent most castings from cracking, but the amount of heat-treatment must depend on the liability of the casting to crack.

Obstinate cases of cracking may be obviated by the use of a combination of methods of moulding, chilling, casting temperature and prolonged normalising. The effect of normalising is to alter slightly the structure of the metal: the cementite areas are slightly broken up and the pearlitic areas become slightly more abundant.

The necessity of normalising certain castings must not be confused with cracking, which may be caused by faulty foundry practice. Cracking is often caused because the contraction of the casting relative to the contraction of the main runner has not been taken into consideration. This fault is often common with very thin and long castings, which require to be gated in several places to avoid what is called misrunning. The main runners, being thicker and stronger than the casting, are the last to cool and contract; in fact, with this type of casting the casting has often solidified and contracted long before the main runner, and when the main runner eventually contracts, the stresses are so great that the casting cracks.

This type of cracking can be avoided by casting from two or more ladles, splitting up the runner accordingly and arranging the gates and runners so that the longitudinal contraction of both casting and runner are equal.

When these thin sections are of the highly repetition class, and speed of moulding and casting is more convenient when only one ladle is used, this cracking trouble may be overcome quickly and easily by breaking the main runner before contraction takes place, without disturbing the casting. This is done by giving the casting head a good blow with a hammer, or, what has often been seen in the foundry, the moulder using his heel for a hammer—a method not recommended, but which is nevertheless effective. The castings are then left to cool normally in the sand.

The Malleablising Process

The cleaned castings are now ready for the malleablising or annealing process. More development seems to have taken place in recent years with this particular part of the process, but the older process in more general use in this country to-day will first be described.

The furnaces used for annealing are various: they vary as much in size as they vary in the method of heating. There are several patent furnaces on the market, each claiming their advantages of fuel economy, mechanical charging, etc., but they are worked on the same principle of heating the charge to the desired temperature for the period of time necessary to soften the castings completely.

The size of the furnace varies with the size of castings manufactured, larger castings requiring larger furnaces, since they require larger pans to pack them in, and furnace capacities vary from a few cwts. to several tons.

Continuous tunnel ovens are becoming more popular, and recent developments in annealing have taken place which have rather eclipsed the old method. The latest method, which it is hoped to describe later, appears to have a very promising future, but this method of short-cycle annealing has not been practised very much in this country.

In the method more generally adopted in this country the castings are packed in heavy cast pans (these are generally made in the foundry), together with a definite mixture of red hematite ore about the size of peas. The mixture is made up of old spent ore from the previous annealings and new ore, the proportion of new ore varying with the thickness of the castings. The packing mixture not only supports the castings through the long period of annealing, but also provides the oxygen necessary to convert the carbon. Lids are provided and all spaces are luted up with sand and water; the furnaces are closed and heated to the required temperature. The annealing is continued for a space of time, depending on the thickness of the casting and, as before stated, the composition of the metal mixture.

The heavy castings are packed in the top pans and the lighter ones in the bottom pans, where the temperature is not so high. Often with some manufacturers the annealing period is as much as eight days, but the general practice to-day is to regulate the silicon and carbon so that a metal mixture is used which will anneal in as little as 48 hrs. at the annealing temperature, that is about five days inclusive of packing the ovens from cold and unpacking (which takes two whole days if the furnaces are not mechanically charged).

Very thick sections will require a little longer annealing, but sections up to $1\frac{1}{2}$ in. will be softened thoroughly in this time; the annealing temperature of the castings is about 980 deg. C., which allowing for temperature lag means that the furnace will be slightly above this figure

Ore Mixtures

The proportion of new ore to used ore varies with the thickness of the castings, and also the ratio of weight of castings packed in the pans; the more dense the packing of the pans, the more new ore will be required. For general purposes the mixture of new ore and used ore will vary from 1 part new to 3 parts used ore, up to 1 part new ore to 11 parts used ore, the weaker mixture being used for the lighter castings.

The old spent ore is not discarded, but is placed out to weather and used again; the weathering rusts the iron that has been reduced during annealing, providing hydrated ferrous anhydride, which acts in a more mild way than the new ore.

During annealing the carbon is not completely removed from the casting; all cementite areas are completely broken up and replaced by pearlite and ferrite areas, with very small particles of temper carbon distributed throughout the structure. The outside rim of the casting is completely decarburised, and if the annealing process is carried on at too great a temperature or the ore mixture is too strong this decarburised rim will develop into a peel, with deleterious results to the mechanical properties.

Malleable castings made from the correct metal mixture and properly annealed should show absolutely no evidence of peeling.

The concentration of carbon is greatest in the centre of the sections, and care should be taken to see that all the cementite is completely broken up, the pearlite occupying about half of the area at least, the other half of the structure being made up of ferrite or pure iron.

Pyrometric control of the furnace is essential if the resulting castings are to be uniform; the recording type of pyrometer is the most popular.

Short-Cycle Annealing: American Practice: Blackheart

The whole of the process of annealing is rather cumbersome, considering the weight of pans and packing material and the time taken for packing and unpacking the castings; this has in a large measure resulted in the evolution of a much quicker and more convenient process of annealing, which entirely dispenses with the use of heavy annealing pans and packing material, allowing much greater ease in handling and considerably reducing the period of annealing.

This short-cycle annealing is carried out in specially constructed continuous furnaces of the muffle type, provided with a pusher type mechanism, which charges the furnace at one end and pushes the annealed castings out at the other end.

The furnace has four separate chambers, the charge passing through each of the chambers during its passage through the furnace; the speed of travel is controlled by the pusher, allowing the castings to remain in each of the various chambers for a definite length of time; processed gas is introduced into the furnace, which prevents excessive oxidation of the charge.

In the first chamber, called the high temperature zone, the charge is quickly heated to the required temperature (about 980 deg. C.), and held at this temperature for the period of time required, depending on the castings to be annealed. The charge then passes into the quick cooling part of the furnace, where cooling tubes regulate the temperature down to that required for this part of the furnace. When the castings have completed their passage through this part of the furnace they are at the temperature of the low temperature chamber, into which they are introduced and allowed to pass slowly through until they arrive at the final cooling chamber, and pass out of the furnace as annealed malleable castings.

The time occupied for the passage through the furnace varies considerably, according to data collected. One malleable foundry reduced the time of annealing after introducing this type of furnace from seven days to 15 hrs., but in this case the furnace was electrically heated.

The castings, as stated previously, are not packed in pans, but are loaded on special trays for their passage through the furnace, the quick heating and perfect temperature control during the various stages of the process, together with the quick method of charging the castings into the furnace, instead of the slow method of packing, resulting in a net saving of more than ten-elevenths of the annealing time when compared with the old-type furnace using pans and packing material.

The capacity of the furnace was 35 tons a day, and the total energy consumption is given as 267 kw.-hrs. per net ton of castings annealed.

Heat-Treatment and Mechanical Properties

The advantages claimed by the manufacturers of this electric furnace are certainly justified by these figures. The mechanical properties of malleable castings can be greatly improved by further heat-treatment. Hardened and tempered, they behave in very much the same manner as steel. Very good results can be had from press tools and bending tools treated in this way, but if the tools are to be used for cutting, it must be remembered that before hardening the decarburised rim of the casting must be first removed, since, containing no carbon, heating and quenching has little or no effect on the hardness.

Hardened malleable iron will give a tensile strength of 60 tons per sq. in., but the elongation is practically nil; the fracture is very similar to that of cast steel. Mechanically, of course, it does not compare with cast steel, and is only intended as a quick substitute.

Malleable castings will not weld successfully. Their welding properties, however, can be improved if special precautions are taken. Very low silicon irons which have been thoroughly annealed give fair results, but they are never quite dependable. Ordinary malleable castings cannot be heated above the welding temperature and retain their malleability. Immediately the heat is raised to the re-solution temperature of iron and carbon, the castings revert very near to the hard condition that maintained before annealing; in fact, this is so pronounced that the writer has found difficulties in machining castings which have become too hot through friction on the grinding wheels during the necessary dressing of the castings.

The British Standards Institution test for whiteheart malleable castings is:—Tensile strength, 20 tons per sq. in.; and an elongation on 2 in. of 5 per cent., with a bend test of 45 deg. over a radius of 1 in. If care is exercised in the choice of new materials, and the metals are mixed to give the correct analysis in the unannealed casting, and the annealing process is conducted in the proper manner, very little difficulty will be experienced in getting mechanical properties in excess of those asked.

Casting temperature and a perfectly sound casting play very prominent parts in improving the mechanical properties. The casting temperature should not be higher than that necessary to produce a perfectly sound casting, and, generally speaking, the castings which in the hard state cool quickest through the critical temperatures of the iron-carbon diagram will be found to have higher mechanical properties.

Fairly low silicon irons or irons in which the carbon is more stable give the best results, but these require more prolonged annealing.

Quite a few manufacturers favour the use of low silicon irons, as these are handled easier from the moulding point of view, requiring very much less feeding apparently; but actually the soundest castings are those made from the slightly higher silicon and more fluid iron, with which special care has been taken to feed properly.

DISCUSSION

EAST MIDLANDS BRANCH

In the absence of the author, Mr. A. E. Davies' Paper was presented to the East Midlands Branch by Mr. H. L. Sanders.

The BRANCH-PRESIDENT (Mr. H. J. Beck), opening the discussion, said he was surprised to note that Mr. Davies had not gone into more detail regarding the method of feeding and gating malleable-iron castings. After a lifetime's experience in the production of this type of casting in a foundry where there were 1,200 to 1,300 different types of castings produced in any week, varying in section from ⅛ in. to 1 in., many of them fragile and of intricate design, he considered this was one of the most essential phases of manufacture.

Methods of feeding and gating could not be described as just skimgate or spinner, as they necessitated careful consideration by the foundry executive before the pattern equipment was produced. In some instances, the best way to mould a submitted design was not always satisfactory from a feeding and gating viewpoint. In many cases, alteration in design had to be suggested by the foundry, as the castings as designed were almost impossible to produce.

When outlaying a casting for production, the following points must receive attention:—(1) Whether to use a spin feeder or skimgate or a combination; (2) whether it will be necessary to remove gates and feeders when casting is plastic; (3) whether to normalise or not; (4) whether to use denseners, and, if so, whether to use them in the core or mould; and (5) where to bracket or tie to prevent hot tears. Mr. Davies could with interest have included data giving particulars of the ratio of weight of sprue to weight of good castings produced.

MR. A. E. PEACE said the Paper was certainly comprehensive and was concise from the point of view that it did not go into very great detail. There were not much data submitted, but it was certainly provocative of discussion and could bear useful enlargement in certain places. When dealing with melting methods, the author referred to decided advantages the rotary furnace had over all other methods of melting malleable-iron mixtures. He did not dispute this, and added that the cupola also had advantages: this might be said for any method of melting.

Graphite, Manganese and Sulphur

In a number of places, Mr. Davies rightly warned against compositions which tend to give primary graphite, that is tended to graphitise during solidification and cooling in the mould. It was most important in malleable that this formation of graphite should be avoided, since the graphite forms in a flakey structure, as in ordinary cast iron, and this structure, on annealing, tended to give network formations which weakened the metal. He asked how the freak composition of 0.8 per cent. sulphur was obtained. Presumably it would be necessary to obtain this composition by the addition of, say, ferrous sulphide. He did not agree with the author's statement regarding manganese and sulphur, that a manganese content twice that of sulphur was desirable. This was excessive for the production of a true whiteheart, and with a manganese content so much in excess of the sulphur there would be a considerable tendency to graphitisation during annealing, and to the production of a semi-blackheart. Referring to the author's statement that "the use of denseners or chills is very popular in the malleable foundry, particularly when high-duty castings are required, or when the castings have to be routine tensile tested, which is often the case with malleable castings," Mr. Peace said tensile tests were usually carried out on test-bars. It was most unusual for tensile tests to be carried out on the actual castings. Further on the writer says:—"Over-chilling should be avoided, since this causes weakness." He (the speaker) was not quite clear as to the manner in which this caused weakness, unless it be by physical defects, such as "cold laps." The effect of chilling upon the properties of the metal was certainly beneficial, producing smaller grain size; and more rapid migration of carbon was obtained, thus facilitating annealing. Regarding the "malleablising process," the author referred to regulating the mixture so that the metal would anneal in a shorter time. This is a matter which he would not dispute, as it depended upon the annealing temperature, and also upon the section of the casting.

MR. SANDERS, in reply to Mr. Peace, said that the cupola and the rotary each had their several advantages as melting media. The cupola was more elastic, but the rotary was stated to give better control of melting and the advantage of a lower carbon content. If a carbon content of below 3 per cent. was consistently maintained in the rotary furnace, it helped the annealing process and in general gave better mechanical properties than with cupola metal where the carbon averages 3.25 per cent. or higher. Mr. Sanders agreed with Mr. Peace about the danger of primary graphite in the castings, as this was fatal. In the case of 0.8 sulphur, it was assumed that Mr. Davies added ferrous sulphide, the castings showed no evidence of primary graphite, as the following extract from Mr. Davies' letter will show:—

> "I do not recommend the use of freak mixtures such as 0.8 per cent. sulphur and 1.2 per cent. silicon, but the resulting unannealed castings showed no evidence whatsoever of graphite, although the section thickness was about one inch. No mechanical tests were taken, the fracture of the annealed casting showed a particularly small grain size, and good results were obtained when the casting was tested to destruction. This instance was mentioned to point out the importance of securing the carbon in the combined condition, and also the neutralising effect that certain elements have upon each other, particularly of silicon and sulphur."

MR. SANDERS agreed with Mr. Peace that with a manganese content of twice the sulphur, one was liable to get varying fractures, such as blackheart or semi-blackheart, depending on the thickness of section and the annealing cycle. Mr. Sanders was afraid, in this statement, he was not defending Mr. Davies too well, but when one was making ordinary malleable castings, he supported Mr. Davies in that the manganese content of twice the sulphur would be very helpful in shortening the annealing time, which would save money and also time in delivering the castings, which was of importance in a malleable foundry. Where one was making true whiteheart castings, the manganese should be approximately equal to the sulphur, or not more than 0.05 per cent. in excess, so that no precipitation of temper carbon could take place.

Denseners and Chills

The point which Mr. Peace had raised was very important, so that Mr. Davies was communicated with and in reply he stated:—

> "Test-pieces cast entirely in chills have always given negative results in my experiments. Various types of test bars have been used; shouldered test bars are hopeless, which is probably due to small contraction during cooling in the mould. With plain test bars, the results were never so good as sand cast test bars. The chills in each case were practically cold. In the case of bend tests of chilled castings where the chill was used on one side of the mould only, the castings bent very well if the chilled part of the casting is the outside, *i.e.*, the tension side, if the reverse is the case and the chilled part of the casting is in the inside diameter, *i.e.*, in compression, then the bend test is as poor as the alternative way was good. Most of the test bars cast in chills were perfectly sound, precautions being taken to make them so."

Mr. Sanders, continuing, said the statement that overchilling caused weakness probably required qualifying, because of the physical defects resulting from the extremely rapid cooling. With a cold chill there was no time for the escape of gas, which hence struck back into the metal and might be trapped there. Again, metal did not lie very kindly on a cold chill, especially if the chill was massive and did not heat up quickly. When chilled castings have been fractured, they have had a fine grain size, which as Mr. Peace said assists in the annealing process.

Mr. Sanders stated he had seen a few malleable castings welded electrically. It was assumed that the castings would be chiefly ferrite and would stand the re-heating without re-solution of carbon. These castings were subsequently machined and it is most probable that under good conditions, welded malleable castings would be quite successful.

Metal Mixtures

MR. T. GOODWIN said the author, referring to metal mixtures, stated that hematite irons are the base of these mixtures. That was bound to be so in cupola practice. He also stated that steel scrap, if used at all, is used very sparingly. He personally had had the unfortunate experience of having to make whiteheart malleable from thin steel sheets and no pig-iron. When Mr. Davies says that the rotary was the best medium he was inclined to agree with him, because the silicon or carbon can be increased, if necessary, which was necessary if large percentages of steel were used, and carbon was really the controlling element. Some people might say that silicon was the controlling element, but he favoured carbon.

Regarding the functions of silicon, the author says "small sections which are very difficult to cast economically in the foundry can be cast quite easily and safely with a mixture of considerably in excess of 1 per cent. of silicon." Exceeding 1 per cent. of silicon in whiteheart castings was liable to cause trouble. He agreed with Mr. Peace that the general practice was for the silicon content to be fairly low.

Hatfield Annealing Cycle

In regard to short-cycle annealing, he would like to touch on an annealing cycle which was devised by Dr. Hatfield some years ago, and disclosed in a comprehensive study. He started off with what is a recognised whiteheart analysis, 3.5 per cent. combined carbon with no graphite, manganese only a trace, silicon 0.50 per cent., sulphur 0.35 per cent., and phosphorus 0.05 per cent. These were packed in the usual manner with a mixture of three of old ore to one of new ore, and it went through the recognised whiteheart process of annealing. There was only one way that one could change the annealing process, and that was if the analysis was altered initially. The annealing took 90 hrs. to reach a temperature between 980 and 990 deg. C., and was held between 990 and 950 deg. for 80 hrs. Therefore, he could not understand this 15-hr. cycle. After the 80 hrs. at 950 deg. C., the temperature was gradually lowered at a rate of 7 deg. per hr., and it took 50 hrs. to cool down to 600 deg., and after that one could not do much harm. During all that time there were 10 samples taken from that anneal, and they were all checked. The first test was taken at a temperature of 750 deg. C., the second at 800 deg. C., the third at 900 deg. C., and another at 980 deg. C. Five other tests were taken while the temperature was at 950 deg. C. The last test was taken when the temperature had reached to 600 deg. C., and that, Dr. Hatfield said, was a perfect sample of English whiteheart malleable iron. The analysis of the finished product was: Combined carbon, 0.65; temper carbon, 1.10; sulphur, 0.35, and phosphorus, 0.05 per cent.

MR. SANDERS said the author's statement that a few years ago manufacturers of malleable castings used almost exclusively a refined hematite mixed only with returned annealed scrap was perfectly correct, and many foundries were using this material to-day. In the cupola, steel scrap was rather tricky and gave difficulty in obtaining even-melting and constant composition. With grey iron there was a little more latitude in this respect than with malleable iron. Evidently Mr. Goodwin also appreciated the rotary furnace, in agreement with the speaker, for it had some very good points. With it one could use straight blast-furnace hematite, steel scrap or ingot mould scrap and obtain a very good mixture. In addition, the bath could be analysed and brought to correct composition before tapping.

Silicon Content Qualified

Mr. Sanders congratulated Mr. Goodwin on making good malleable out of his mixture; good malleable, whether blackheart or whiteheart, was very dependable. Mr. Davies qualified his 1 per cent. silicon for castings of $\frac{1}{16}$ in. section. Frankly it seemed very thin, and such thin sections had fortunately never been his (the speaker's) experience. In the thinnest class of work, such as conduit fittings, 0.8 per cent. silicon was specified, and for pipe fittings a little lower. Many castings were sold at so much for each and the foundry was anxious to cut down the section thickness, so that the result was a compromise between making good castings and not giving away too much weight. The quotation from Dr. Hatfield's experiments was very interesting; when it was studied it was realised that it was practically modern whiteheart practice.

Regarding the statement about 48 hrs. at the annealing temperature, the author writes:—

> "The practice I use, and have used for the past 15 years, is to light the furnace on, say, Thursday night at 5 p.m. The furnace, 3 tons capacity, is well up to heat by 5 p.m. on Friday; firing is continued on Saturday and until 5 p.m. on Sunday, making 48 hours' firing time at heat. At about 8 p.m. on Sunday the front of the furnace is pulled down and the furnace is unpacked on Monday. I have only five annealing furnaces, and get five ovens per week from them. The furnaces are not mechanically charged; all packing and unpacking is done inside the furnace. Most of the castings are of light section, but the thicker sections are placed on the fire side of the furnace, where the temperature is greatest. A strong mixture of ore, 1 to 3 is used for thick sections. The mixture is a hematite steel mix with analysis as follows:—Silicon, 0.5; sulphur, 0.14; manganese, 0.30; and total carbon, 3.0 per cent."

MR. J. ROXBURGH said, although the Paper was intended as a survey, he would suggest that, being so general in character somewhat detracted from its value, as it was only by the study of the details of the production of a great variety of malleable castings that the inherent difficulties and problems were revealed.

Characteristics of Malleable Casting

Fundamentally, malleable iron had a higher casting temperature, a higher initial freezing point, a shorter freezing range and higher solid contraction than cast iron. The two phenomena, which exerted the greatest influence, therefore, were liquid shrinkage and solid contraction, although the running properties of malleable iron presented difficulties, too. The running and feeding of malleable castings, as well as the precautions to be taken to avoid trouble due to solid contraction, were considerations even more vital than with grey-iron castings.

In view of this, initially, the design of malleable castings was most important, and he felt that, in the main, judging from the foundry aspect, greater consideration should be, and was, given to this question with malleable castings than was the case with grey-iron castings, and, quite frequently, the manufacturer, before commencing production, was obliged to ask the customer for some alteration to design to ensure soundness in a particular casting or to facilitate production. These suggested alterations almost invariably were approved, and by such co-operation mutual benefit was derived.

The behaviour of the casting, after pouring, in changing from the liquid to the solid state, was most important, and it was the aim of the manufacturer to endeavour to control or direct such solidification, so that appropriate measures might be adopted to guarantee a sound casting. The disposition of the runners and feeders were therefore determined with this object in view, and where thick and thin sections occurred in a casting, the difficulties of feeding were increased, particularly if the thick sections of the casting, due to the method of moulding adopted, were so placed in the mould as to render them difficult of access. There were several types of feeders in general use, such as top feeders, side feeders, joint feeders, running feeders and off-feeders.

Mr. Roxburgh then emphasised that the ratio of feeder and sprue to the weight of casting was important, particularly so in wartime, and had found by experience that the investigation of this question had well repaid him.

Defects and Mould Material

Regarding defects, which occurred in malleable castings, there were those which were common to any casting, but in addition there were others which were peculiar to them, to some of which the author had made reference. He mentioned that cracking was liable to occur with certain castings, but omitted to refer to "hot tears," "pulls," warping and distortion. Special precautions had to be taken to endeavour to avoid much trouble, and the use of "ties," brackets, lightening out of cores, etc., was resorted to.

Another question, which was important, was the material which constituted the mould. Malleable castings were usually made in green-sand moulds, but variations in results could be obtained by the use of natural moulding sand as compared with synthetic sand, the latter usually having less moisture content, and higher bonding strength and permeability. Again, the use of denseners in moulds should be avoided where possible, but they were quite frequently employed to ensure soundness. A combination of feeder and densener could be very effective, particularly from the point of view of reducing the amount of feeding metal required and ensuring that the casting was white and free from graphite as cast. The cleanliness of running of any casting was important, but with malleable iron, strainer bushes and "grids" should invariably be used to prevent slag or sand entering the mould.

Mr. Roxburgh said they were all indebted to Mr. Sanders for having presented the author's Paper and for dealing with the discussion.

MR. SANDERS, in reply, said that unfortunately there was little detail in the Paper regarding the gating and feeding of malleable castings. He did not know Mr. Davies' foundry but he imagined it was very different from the one where Mr. Roxburgh was engaged, which manufactured the most comprehensive range of castings in the country, from the lightest to the largest and most complicated. Malleable castings ranged from ironmongery fittings to heavy engineering castings, and obviously the former did not present many problems to the foundry manager. His chief problem was to make them cheaply and quickly.

Control of Solidification

He agreed that malleable iron had a high liquid shrinkage and high solid contraction which made the founding a much more difficult problem than with grey-iron castings. The only way to tackle these problems, especially if the order was for a large number of castings, was first to study the drawing and see if any useful modification of design could be made. Secondly, various methods of moulding, gating and feeding should be tried off a loose pattern and when these points are finalised the plates with runners and feeders can be adjusted and put into production. A study of directional solidification would indicate where the feeders were to be placed. The top feeder was very useful but one had to be very careful to avoid sinking around the feeder, caused by the weight of feeder forcing the supporting sand into the casting. The side feeder on the joint was generally superior, particularly in production moulding.

He asked what Mr. Roxburgh meant by the off-feeder? The value of a chill under a section of the casting which was also fed was emphasised, one advantage was that less feeder was necessary and another was that it removed the danger of primary graphite. Mr. Davies gave some ideas about normalising to prevent cracking brought about by casting stresses in the mould. Whiteheart castings were much more liable to cracking than blackheart and with the thin plate type of casting the only way was to muffle the casting as soon as possible after casting to take care of solid contraction stresses. Any cores must be capable of collapsing quickly under contraction.

Information on the effects of synthetic *versus* natural sand was invited. Another difference between malleable and grey iron was the difficulty of keeping out slag inclusions to which whiteheart malleable was very prone. Mr. Sanders relied almost exclusively upon the spinner ingate, if this was quickly filled with metal it was possible to keep the dirt out of the castings.

"Over-Chilling"

MR. J. BUTTERS said, under the heading "Moulding and Casting," the author advises the use of chills, and states in the same sentence that over-chilling should be avoided. What is over-chilling? In the Paper, under the heading "Malleablising Process," the author states: "Often with some manufacturers the annealing period is as much as 8 days, but the general practice to-day is to regulate the silicon and carbon so that a metal mixture is used which will anneal in as little as 48 hours." Would the properties of the castings be as good in each case? If this be so, then the country was losing a lot of time in the malleable business.

MR. SANDERS, in reply, said that by the term "over-chilling" it was assumed that Mr. Davies was referring to castings cast completely or nearly so in chills such as the test-bars completely chilled. When casting in chills, there were fundamentally different conditions from casting in sand; the conductivity of the chill was greater, permeability was zero and the resistance of the chill to solid contraction was infinitely greater. There was also the question of the temperature of the chill which had a great effect in controlling the speed of solidification, particularly of the skin of the casting with the secondary effect on escape of gases.

The time of annealing depended upon two factors, the composition of the metal and the section thickness. Probably in the case cited by Mr. Davies the composition had the greater effect because it ensured the precipitation of temper carbon in thick sections so that these annealed in as short a time as the thinner section. With true whiteheart annealing, *i.e.*, with removal of carbon by oxidation and no graphitisation, for a thick casting the annealing time could easily be 8 days. If the manganese was a little higher the annealing time could be reduced considerably and a very good quality of malleable thus made.

Chills and Feeders

MR. E. HOLLAND said the Paper states: "Where a casting is being chilled, it must be well fed." Yet he failed to agree with this statement, as if it were well fed, it did not need to be chilled; chills usually being placed where feeders were impossible or not advisable. There was also a statement that a moulder used his heel or a hammer to break off the runner to prevent cracking or pulling. On a round plate type of casting this could not make much difference as the runner mouth was the weakest point owing to it being the last to solidify. The solid contraction around the periphery would pull this joint apart even if the runner was broken off.

He understood Mr. Sanders in his reply to Mr. Peace to state that the annealing oven was opened three hours after firing had ceased. He did not understand how successfully annealed castings could be obtained with this practice, as the drop in temperature from 980 to 710 deg. C. in three hours would be far too swift.

MR. SANDERS, in reply, said a chill was frequently used under a feeder in malleable practice. A feeder might be used alone, but a chill alone would not serve the purpose. It was generally admitted that a chill did not cure unsoundness, it merely removed it to another place. If the casting could be chilled in one place and fed in another, this was recommended, as the freezing rate of the part away from the feeder was accelerated. An example was given of two bosses on a casting joined by a web. A feeder could be used on each boss or one boss chilled to reduce the cooling rate to that of the web when a feeder on the other boss would adequately feed the casting.

Cleaning before Annealing

The correct time to clean whiteheart castings was before annealing. If sand was left on, the annealing process was delayed and the burnt-on sand was much more difficult to remove. If a long thin casting was run with several ingates from a long spray as grey iron practice, the casting would cool first and contract, and would be in a stressed condition when later the runner spray cooled and contracted. It was better to knock off the runner before this could happen or, better still, to cast such a casting with two or more downgates, and to break off these to allow free contraction of the casting.

The cooling time from "cease fire" to opening of the wicket from 5 p.m. to 8 p.m. was surprisingly short. The oven was quite small, holding only 3 tons of castings, and would cool fairly rapidly, but not quickly enough for any ill effects on whiteheart castings in the cans.

Vote of Thanks

MR. R. H. BUCKLAND, in proposing a vote of thanks to the author and Mr. Sanders, said he had been particularly surprised at the very bold statements made by the author in the Paper. The author had said that it would not be correct to state that malleable castings were as good as or as dependable as the best steel forgings or castings. Actually a good malleable casting and a good steel casting were both dependable, but some steel castings were not reliable. He could not agree that chills were popular in malleable foundries, although they were apparently appreciated by Mr. Davies. However, he supported other speakers' views that chills could be used very profitably, especially in conjunction with feeders, where a considerable amount of feeding metal could be saved. After MR. POLLARD had seconded, the vote was accorded, and the meeting closed.

DISCUSSION

LANCASHIRE BRANCH

MR. E. LONGDEN said the bulk of the metal for the whiteheart process was formerly melted in the cupola furnace, and he assumed that such was the case at the present time. Necessarily the cupola product gave the whiteheart metal, since the difference between whiteheart and blackheart consisted in the manganese and sulphur contents. When melting in the cupola the sulphur was on the high side, and this necessitated higher annealing temperatures and longer periods of annealing, and the production of a harder variety of malleable iron than blackheart which had been termed malleable steel. Whiteheart malleable iron was far more in demand than the blackheart for certain parts of machines where stiffness was a required property in the malleable metal.

Straightening the Final Product

The analysis of the metal brought to mind the need for straightening castings after annealing. The packing and the weight of the metal of the pans created distortion, and, in his time, straightening processes were resorted to after annealing. The castings were heated up and straightened with hammers and dies. He had not experienced any great amount of hardening effect if the castings were properly dealt with after heating up again. It was really an after-treatment. This was a point which should be borne in mind.

He did not know whether the metal which Mr. Davies dealt with was different from that which had come under his own observation, but when properly dealt with whiteheart malleable iron could be worked without any undue hardening effect.

It was said that after all there should be very little free cementite about a casting if it was properly annealed, but he could not agree with the statement because in thick sections there was bound to be a certain amount of free cementite, taking the average annealing period of the oven. The annealing temperature was given as 980 deg. C. Did Mr. Davies maintain that temperature when the oven was thoroughly soaked? Was it not the rule to lower the temperature to about 900 or 920 deg. C. with beneficial effects on the casting?

With respect to the tunnel annealing of malleable iron, perhaps Mr. Davies would state what was the kind of malleable iron to which he referred. It would hardly be whiteheart, because he suggested there was a neutral gas present which prevented undue oxidation of the material, and whiteheart malleable iron depended upon oxidation to give it the properties required.

Sand for Whiteheart Practice

Any information concerning the sand used would be acceptable; for instance, was a sand used similar to that prepared for ordinary grey iron green-sand casting? He believed the practice was to use slightly more, though not an excess of, coal dust in the sand. Of course, dry sand would be used for the larger castings. The point was, apparently, that since the castings were brittle more coal dust was introduced, because it caused the sand to drop away from the casting more easily, thereby avoiding the trouble of brushing and a certain amount of handling.

Dealing with the proportion of new ore to old ore, in the case of a foundry making a general run of castings, it would be difficult to segregate sufficient castings to apportion the ore in an oven. Did Mr. Davies suggest that an ovenful of ore would contain in the pans varying proportions of ore? Did he mean that in the case of a heavy boss section he needed practically all new ore in order to create the maximum amount of oxidation in a part which would require it?

Ore Mixtures

MR. DAVIES, dealing with the proportion of new ore and old ore used for annealing purposes, remarked that the general principle was to vary the ratio of new ore used for each particular casting, taking into consideration maximum and minimum section thicknesses. In such a case provision would be made for an ore mixture to deal with the thicker part of the casting, and the thinner part of the casting would be more or less ignored. Castings were packed in pans, the size of the pans varying according to the size of the castings. In general practice small pans were about 13 in. dia., and probably 14 in. high. They were packed in tiers in the pans, sometimes about six high, according to the height of the furnace. It was the practice to vary the iron ore according to the thickness of the section of the casting. When annealing castings approximately 4 in. long, having a section of only $\frac{1}{2}$ in., probably an ore mixture of three parts of old ore to one part of new would be used.

Melting Furnace Changes

Turning to the question of melting furnaces, Mr. Longden had mentioned the cupola as being the most popular melting medium. This used to be the case some years ago, but to-day, in the malleable-iron foundry, the cupola was definitely losing ground, chiefly on account of the use of hematite and steel mixtures. When using a cupola, the fact would be appreciated that by using a hematite pig-iron the material would contain up to about 1.4 per cent. of silicon. A mixture with steel scrap would bring about the desired analysis. Steel scrap contained but little silicon. It was a case of mixing a material with minimum silicon with another material containing about 1.4 per cent. silicon. Again, the melting point of steel as compared with hematite iron was very different. Hematite pig would melt at a temperature of somewhere about 1,150 deg. C., while for steel a temperature of 1,350 or even 1,400 deg. C. was necessary.

The cupola was certainly not popular for melting two irons having such a disparity in silicon, because the silicon percentage was most important and must be uniform. This consideration had favoured the rotary furnace, though it probably did not cost very much more, in order to get the iron at the required melting temperature.

Another matter which tended towards the disuse of the cupola was the steel scrap which had to be used in cupola practice. Punchings were very popular and very cheap, but they were not suitable for cupola melting, because they trickled down into the well of the furnace, with the result that there was a hopeless mess. The general principle was to use steel which was large enough not to trickle through the coke, and which would remain in the charge until it got into the melting zone.

Another feature which militated against the adoption of cupola practice was the carbon pick-up. The usual practice was to keep the carbon content as low as possible during melting, though there must be a certain amount of carbon in the charge in order to induce fluidity in the iron.

Press Tools

A question had been raised concerning machine tools. Perhaps he had somewhat misled his hearers with regard to that subject. He did not mean that malleable-iron castings, hardened and tempered, would approach anything like the quality of high-speed tool steels. In the case of presses and the like, malleable-iron castings were definitely of great assistance if a tool or die was wanted quickly. When it was desired to start with a piece of cast steel or high-speed steel it was machined out of the solid, whereas with a malleable-iron casting the casting could be made practically to the required shape during the moulding operation. Very little had to be taken from the casting in order to clear the ferrite area, which was really the outside and contained absolutely no carbon. Generally speaking, the casting itself would yield carbon content of between 0.4 to 0.8 per cent.

It was an advantage when making press tools to arrange the annealing so that the carbon was not completely removed, the percentage of carbon present being round about 0.7 to 0.8 per cent. This was almost the eutectic composition. Practically the whole of the structure of the iron intended to be used for press tools would be pearlite. By adjusting the annealing process sufficient carbon could be retained in the malleable-iron casting to harden and temper it.

He had frequently used press tools made of malleable-iron castings. The fact that with hardened malleable-iron castings, a tensile strength could be obtained in excess of 60 tons to the sq. in. proved that there was quite an appreciable amount of carbon left in the casting.

The Upsetting Process

Malleable-iron castings were certainly straightened, very much to the annoyance of the foundry manager, but if they were heated to 850 deg. C. they were not hardened at all. The general practice was to heat the castings to about 750 deg. C. The castings could then be straightened in the press, or hammers could be used; very little difficulty would be experienced in straightening the castings.

Malleable-iron castings could be heated up to 700 deg. C. and quenched with water and still retain quite an appreciable amount of their malleability. They were not hard, but the carbon in the casting was immediately hardened at a temperature of 850 deg. C.

If castings were properly annealed there should be no cementite in the structure at all; the cementite was broken up. With cementite there was pure iron carbide of the formula Fe_3C.

If during annealing the temperature was maintained at about 980 deg. C. for 36 to 40 hours, and then reduced to about 850 to 900 deg. C. the quality of the malleable iron would be definitely improved. Any tendency to get castings in and out of the oven as quickly as possible should be restrained though the practice did not deteriorate the castings to any very great extent. Castings which were annealed at the maximum temperature of 980 deg. C. throughout the whole of the process would certainly comply with the B.S.I. requirements for mechanical test.

Coal Gas in Tunnel Ovens

When using the tunnel oven for blackheart malleable iron castings, a blackheart mixture was not actually used, but rather a composition intermediate between that and whiteheart. With regard to the process gas used, the tunnel was supplied with ordinary coal gas in definite proportions in order to provide an atmosphere which contained sufficient CO_2 to react with the iron carbide in the casting. Where the castings were packed in pans the CO gas burned at the top of the pans. Of course, this could not be seen in the case of the tunnel oven. The process gas was produced to give a gas which would not be excessively oxidising in its action but which would remove the iron carbide from the malleable-iron casting. Fortunately, iron carbide was very easily removed; much more easily than was the case with free graphite which was very difficult to remove in the case of a hard casting, and, in fact, if it was removed the tendency was to create cavities.

Sand Mixtures

Sand mixing was very much the same for malleable iron castings as for grey-iron castings, although the metal for malleable-iron castings was not quite as fluid in character. The permeability of the sand must definitely be very high; if it was not, then there would be very great difficulty experienced if the castings were extremely thin.

Coal dust was a very useful substance in malleable-iron foundry work, but for very thin sections its use was dispensed with as much as possible, reliance being placed mainly upon the coal dust in the heap sand.

High Sulphur and Casting Temperature

MR. R. S. TURNER said that there appeared to be a high sulphur content used in a mixture of hematite and steel. Was the sulphur purposely introduced? Also, was phosphorus detrimental to malleable irons? When advocating that the casting temperature should be as low as possible, was not this likely to induce blowholes and slag inclusions? Again, did process gas replace the ore, or was it in addition to the ore?

MR. DAVIES remarked that the quality of malleable castings was definitely improved the quicker the castings were cooled through the various stages to be associated with the iron-carbon diagram. Temperature did much to heat up the sand, and cooling took place more quickly if a temperature was used which was just sufficient to cast the casting properly.

There was never much phosphorus present in hematite iron, but occasionally batches arrived carrying more than usual. The practice was to use a hematite iron with as little phosphorus content as possible. The B.S.I. specification set the maximum at about 0.3 per cent. Such a percentage did not cause any trouble in the foundry. High phosphorus would cause a great deal of trouble, and make castings very brittle; in fact, more so than would sulphur. A sulphur content of 0.8 per cent. would certainly be excessive; it would be ridiculously extravagant. In one case sulphur was introduced experimentally by melting iron sulphide with the charge in a pot furnace. The quality of the iron obtained with a silicon content of 0.8 per cent. was surprising, and went to prove that high sulphur and high silicon contents were of considerable help in regard to the fluidity of the iron. The higher the silicon content the more fluid the iron. But since it was necessary to preserve the carbon in the combined state, and there was a greater tendency for the carbon to exist as graphites, adjustments must be made to prevent this, and so sulphur was used. Generally speaking, the sulphur pick-up in the cupola was very great.

MR. TURNER said he meant from the point of view of the rotary furnace.

MR. DAVIES said that, from the rotary furnace point of view, the sulphur content was definitely much lower. Hematite irons might have a silicon content as low as 0.4 per cent., whilst other qualities would be definitely grey. There were charcoal irons which could be bought with a silicon content of 0.5 per cent.

MR. HAROLD HAYNES, referring to the metal mixings for the cupola and for the rotary furnace, asked whether Mr. Davies added silicon when the metal was tapped out of the rotary furnace, because he (the speaker) thought silicon losses were appreciable in this furnace.

Points upon which he asked for additional information were contraction; camber; and the rusting of castings. Some foundries allowed the hard castings to remain in the rain for rusting purposes. Judging from personal experience, every casting should be so treated, as it favoured machine-shop practice.

Modern Rotary Furnace Practice

MR. DAVIES said that, generally speaking, the silicon content was reduced during melting in the rotary furnace, but many people manufacturing malleable-iron castings by this process introduced the subsequent charge into the previous charge, that is, they would melt the whole of the cast, but would use only half of it. Thus, when the furnace was half empty, a new charge of hematite iron and steel scrap would be introduced. This became immediately covered by molten iron which prevented the oxidation of silicon to a very large extent. Quite a number of people using the rotary furnace were doing so in order to obtain a more frequent supply of liquid metal.

Camber was never put on a pattern for malleable-iron castings intentionally, unless it was of a very heavy character. Even these did not warp very much, and the camber was very rarely used, chiefly owing to the fact that malleable-iron castings were not made in such large sizes as grey-iron castings. A malleable-iron casting of 5 cwts. was a particularly heavy one from the malleable aspect.

Weathering Malleable Castings

He quite agreed that castings were improved by being put out to weather. He thought this was due to a large extent by the rust getting underneath any sand which was left on the castings, so that the sand came away very easily. Much trouble could be caused owing to sand becoming fused on a casting. If a casting to be machined was perfectly clean and free from sand, very little trouble was experienced with the machine tools; but immediately a high-speed tool touched a bit of sand, its edge was gone. As a matter of fact, it was much easier to machine castings which were somewhat on the hard side rather than castings which contained sand on the surface. Hard spots on castings could prove to be very inconvenient from the machinist's point of view, and though he might be wrong, yet his opinion was that they were caused through splashes of metal created during casting. Hardness from spots in casting could be greatly reduced if the metal was not allowed to splash at all when it was going into the mould.

Panless Annealing

MR. E. LONGDEN said that reference had been made to the tunnel annealing oven not needing pans. Had Mr. Davies experience of work with an oven in which cast-iron pans were not used, either rectangular or round ones? Take the case of an oven constructed with a central chamber, and about 15 ft. in length, 10 ft. in depth, and with two fenders running the whole length of the oven, rising to within about 18 in. of the surface at the top of the oven, and the width of the chamber being something like 2 ft. The castings would be packed practically between the two big fenders, the whole being something like 5 tons weight in the ordinary way. The gases were caused to descend through the centre of the packed castings, through tubes, and also through tubes right at the end of the oven proper. Of course, the usual brick fender was built up round the doors. While it took longer to heat up the oven to the required temperature, namely, something like 40 hours, the castings were thoroughly annealed, allowing for the extra soaking period. From the point of view of economy, it would be found well worth while to use such a type of oven with ordinary pans. The pans did not last very long, perhaps for five or six heats, and, considering the economics of the job, he would have continued to use such ovens had he remained in the trade much longer.

Mr. Davies said that many years ago he conducted experiments on the lines indicated by Mr. Longden, but without achieving satisfactory commercial results. It seemed to him that the method was very similar to the one adopted in the new process of cycle-annealing, apart from the fact that a definite process-gas was used to prevent oxidation. He could quite imagine malleable castings could be obtained from an oven of that type, but there would probably be excessive oxidation of the skin of the casting. He had also used an experimental laboratory muffle furnace. First of all, he passed the gas through the furnace before he passed it to the burners. It was a very wasteful method. He was speaking of about 20 years ago when short cycle-annealing commenced. Some amount of malleability was created by passing the gas over the casting before it went to the burners of the furnace. The burners were at the bottom of the heating chamber.

Mr. Davies then drew a diagrammatic sketch on the blackboard indicating the type of furnace used.

The gas was passed from the main through the chamber containing the particular casting. It then came out from the back of the furnace, and went in to the burners. By this method the castings were certainly annealed, but it was a very expensive operation. Generally speaking, the older method, coupled with the economy in pans, was not very expensive. A pan usually lasted for six heats when using an optimum temperature of 980 deg. C. Five lives were considered to be fairly good, and six lives somewhat exceptional. As a matter of fact the pans, at the end of the sixth time in the oven, were no thicker than paper. It was not economical to use them when they were so thin, because very often the pans would be holed, with the result that castings would be spoiled.

Fuel Requirements

Mr. Longden inquired whether coal was used as the heating medium for annealing? Was it a hard fuel or pulverised coal?

Mr. Davies replied that the type of furnace he definitely favoured was the old-fashioned type using hard coal. The success of the furnace depended upon this, otherwise the required temperature could not be effectively obtained. Since hard coal was not mined in Lancashire, resort was had to the West Cannock Collieries. The furnace was built up in the shape of an arch, and had a solid bottom. The flues came out from two places in the bottom of the furnace, at the back of the wall, and connected with the main flue. In the particular furnace to which he referred, there were three rows of annealing pans when looked at from the front; but actually there was a depth of probably eight or ten pans. The capacity of the particular furnace he used was 115 pans, and the hard coal was simply thrown in through a door to the side. There was no retaining wall for the coal, which simply went right alongside the pans. Very little trouble arose from what was a common fault in annealing—that of having the castings not annealed in the bottom part of the oven. It was very questionable whether there was 0.5 per cent. of castings not sufficiently annealed.

His firm dealt with castings which were definitely grey iron. He had had considerable experience with furnaces which were on the market, and he thought that with coal-fired producer type furnaces it was certainly economical from the fuel standpoint; there was difficulty experienced from the bottom pans not receiving sufficient temperature, so that the resulting castings were unannealed.

Consideration had recently been devoted to the use of pulverised coal to fire furnaces. About 30 h.p. would be necessary to pulverise the quantity of coal required, and having regard to this figure there would not be any economy effected by a changeover to the use of pulverised coal. Personally, he favoured the use of Staffordshire hard coal for annealing malleable-iron castings.

Alternative Fuels

Mr. Longden said his experience had been similar. He had not actually used pulverised coal, but he had used producer gas. There was not a uniform temperature obtained throughout the whole of the furnace as was the case with a straight hard-coal fired furnace. He was surprised to learn that coal was charged directly parallel with the door of the oven. The ovens he had in mind had just a short fender which would allow the gases to circulate and penetrate down to the bottom, being pulled down by the flues, and not impinging directly on the pans; which there would be a tendency to be if the coal was fired directly on the floor of the oven.

Mr. Davies said that in the case of the particular process of annealing he was describing, for instance, an oven which was packed, if work had begun on Thursday morning, say, the castings would be coming out of the oven on the following Monday. A certain amount of economy in pans was sacrificed because the castings were wanted very quickly. The method certainly made much better working temperatures possible. The incandescent fuel, being in contact with the cast-iron pans, certainly caused the bottom pans to wear a little. The wear could not be regarded as excessive.

Temperature Control

Mr. E. J. L. Howard asked whether there was any pyrometrical control of the annealing oven? If so, where was the pyrometer placed? If the oven was packed on Thursday morning, and the castings were withdrawn on the following Monday, that was a five days' annealing. Was the temperature taken up to 980 deg. C., held there for a short period of eight or 12 hours, and then brought down to about 850 deg. C., and held there, and then brought down slowly, then held, and taken up again, and then brought down? He understood that was the American practice.

After stripping the castings from the mould, were any precautions taken to relieve stresses, such as a short heat-treatment of a few hours, prior to packing for annealing?

After welding or brazing was it necessary to heat-treat malleable-iron parts, as he had known of cases where fractures occurred? This trouble had been overcome by a short normalising.

MR. DAVIES remarked that pyrometrical control was essential for the manufacture of malleable-iron castings, but pyrometrical control of furnaces could be very misleading, because if the end of the pyrometer was put into the furnace, then there was a tendency not to record the temperature of the furnace, but to record the heat of the flame.

Dealing with the five days' annealing, the castings were packed on the Thursday and the furnace lighted up during the Thursday evening, usually about 5 o'clock. It was expected that the furnace would be up to 980 deg. C. at least, and often it was in excess of that temperature. Allowing for temperature lag, 1,050 deg. C. were obtained in the first 24 hours. At 5 o'clock on the Friday evening it was claimed that the temperature of the castings was 980 deg. C., allowing for temperature lag. This temperature was maintained for 48 hours. On Sunday night the furnace was knocked down. The front of the wall of the furnace was pulled down and the castings were allowed to cool normally. Unless a casting was required for high duty, then the ordinary process of annealing at 980 deg. C. was sufficient.

Normalising

Normalising had been mentioned in the Paper. It was necessary to normalise certain types of casting in order to prevent cracking during annealing. The castings were taken from the sand as quickly as possible, and transferred into a normalising furnace at a temperature of about 850 deg. C. They were then normalised for 8 hrs., and allowed to cool down in the furnace. When the castings were taken from the furnace, they should be cool enough to handle quite easily. Particular strains and stresses were brought about by uneven cooling and alteration to structure of the iron, thus causing the cementite areas to be broken up with a slightly more abundant pearlite. Actually the difference was very small and could only be detected under the microscope; but it certainly did take place. If a malleable-iron casting, which was very thin, was held up and made to "ring," the reverberations were so numerous that they would continue for a matter of 10 min. or so before they ceased. When an ordinary casting had been normalised, it gave an ordinary "bell" tone which quickly died away; and this was one of the indications that the normalising had been done sufficiently. By "ringing" it was possible to foretell whether there was a tendency for the casting to break during a subsequent operation, and whether it was necessary for it to be normalised.

In the Lancashire district there were castings which were put on the ends of the beams in the looms. Some difficulty was originally experienced with regard to this particular type of casting. The man at the oven often used to listen for the castings to crack when they were being annealed. Perhaps 90 out of 100 were cracked. This difficulty was overcome by alterations of metal mixtures and by proper normalising.

Blackheart v. Whiteheart

MR. T. MAKEMSON wished to congratulate Mr. Davies upon having prepared a very concise review of the art of manufacturing whiteheart malleable castings.

In any discussion respecting malleable castings it was inevitable that there should be a comparison made between whiteheart and blackheart, although this was not quite fair to Mr. Davies, who had rigorously confined the subject matter of his Paper to whiteheart. On the whole, the concensus of opinion appeared to be that better results were obtained from blackheart castings. The B.S.I. tests for blackheart castings were more rigorous than those imposed for whiteheart castings, but whereas the very best blackheart castings might be better than the best whiteheart castings it was very easy for inexperienced people to go wrong with the former.

There were many elaborately designed annealing furnaces at the present time, but some of them were not necessarily better than the comparatively simple type which even Mr. Davies preferred to use. Quite a large number of malleable castings were being successfully annealed nowadays in ordinary brick kilns.

When a casting was made in a grey iron foundry it was made, and usually no further trouble was experienced with regard to it until it arrived in the machine shop. In the case of a malleable casting the foundryman had to contend with the additional process of annealing, and straightening became an important matter.

He knew of a large malleable iron foundry which made motor vehicle castings where every casting made in the foundry was put into a press and pressed to the required shape in dies. This was a practice which, although it involved considerable capital expenditure, produced accurate results.

He surmised that one of the reasons why whiteheart castings were popular was that they could be made quite successfully from the cupola, although, as Mr. Davies had pointed out, some other kind of furnace was better if the foundryman was prepared to instal it. Cupola blackheart castings were not an easy proposition. There were many cupola blackheart castings being made, but the work had to be done by people who had had considerable experience in their manufacture. It was preferable to have some other kind of furnace; either an air furnace, an electric furnace or an oil furnace, while in one case, in this country, an open-hearth furnace was used.

The motor vehicle industry had opened a field of activity for malleable. It would be advisable for anyone who was considering taking up the manufacture of malleable iron to do so upon a strictly scientific basis from the very beginning. This was what Mr. Davies had done, and it was the way in which most firms successfully manufacturing malleable iron had commenced.

MR. DAVIES said blackheart malleable castings were definitely superior to whiteheart castings, but they required much more careful handling and sand control; particularly from the sulphur, silicon and carbon points of view.

Scrap Absorption

MR. A. HOPWOOD asked whether there was any difficulty in utilising, say, heavy fettling shop returns in all their varieties? He presumed that they were fairly heavy in the case of malleable cast iron. What was their proportion; also, what was the proportion of new metal, if one liked to call it so, of hematite pig, or hematite scrap which was used?

MR. DAVIES replied that annealed returns did not cause any great trouble to the general organisation of a malleable-iron foundry. Years ago it was considered to be bad practice to put annealed malleable-iron castings into the charge; but to-day it was frequently done. With scientific control, there was no reason at all why it should not be so. For instance, if a charge of nothing else but malleable-iron castings was put into the furnace, there would be a finishing up with a hard iron perfectly white which was very similar to the ordinary material used with refined hematite. The sulphur would probably be higher, the carbon would not be so high, while the silicon would certainly be lower. With scientific control, balancing other ingredients put into the cupola along with the annealed scrap, there was not much difficulty experienced; but it was important to control the sulphur and manganese in the ordinary way. There should always be about twice the amount of manganese in the charge as sulphur. Otherwise, there did not appear to be any reason why the annealed malleable scrap from the fettling shop should not be introduced into the furnace.

The best castings were certainly made with virgin iron, as representing a uniform charge. If it was desired to make really good malleable-iron castings, the best course was to use nothing but refined hematite. Of course, economically speaking, this could not be done. There had to be a mixing with the ordinary foundry scrap and also with the returned annealed scrap. Returned annealed scrap was often disposed of by making it into pans, though he himself used a mixture of hematite and steel.

MR. HOPWOOD understood that Mr. Davies had charge also of a grey-iron foundry which, under present conditions, was an advantage some foundrymen did not enjoy. If phosphoric irons which were not wanted in a malleable-iron foundry were utilised in a grey-iron foundry, the result would be reasonably strong castings in the grey-iron foundry.

Cheap High-Duty Irons

MR. DAVIES said that if a high-duty grey-iron casting was required, the proportions were mixed in, and often a pot was sent to the malleable foundry to be filled in with two-thirds of malleable iron. In the result, a product was obtained with a very good tensile strength and which machined fairly easily.

MR. B. B. KENT asked whether for normalising malleable casting could be heated up to 850 deg. C. without hardening.

MR. DAVIES said there would be no hardening owing to the fact that the castings were slowly cooled after the normalising process. Actually, there was no reason at all why they should not be heated to 980 deg. C., provided it was followed by slow cooling. If the casting was heated to 850 deg. C., and then quenched with water, the result was that the malleable-iron casting became almost like cast steel. That hardness could be reduced by tempering.

Fracture Considerations

MR. HOPWOOD said he always thought that whiteheart malleable was essentially a decarburised product. From what he had heard during the reading of the Paper, and in the course of the discussion, it appeared to be a mixture of the two. Apparently, there was only the skin which was completely decarburised, while the rest of the carbon was brought out of solution in a spheroidised form of graphite. Could Mr. Davies explain why its deposition in that form in the whiteheart process did not colour the fracture in the same way as occurred with blackheart?

MR. DAVIES said the whiteheart process of manufacture incorporated a decarburising effect. There was probably about 0.3 or 0.4 per cent. of graphitic carbon in an unannealed casting, and after completely malleablising, the percentage would go from 0.3 to 0.8 per cent., or there might even be 1 per cent. of total carbon, made up of little nodules of temper carbon, which certainly in some cases did darken the fracture of a whiteheart casting. With the more popular method to-day, with higher silicon, there was a mixture between the blackheart and the malleable, although it was definitely a decarburising process for the manufacture of whiteheart castings. With the blackheart casting, theoretically there was no decarburisation at all. It was simply a matter of breaking up the carbon and splitting the carbon nodules into tiny nodules of temper carbon. The packing for blackheart castings was usually sand or cast-iron swarf. No oxygen was introduced into the furnace. It was a rearrangement of carbon rather than a removal of carbon. In fact, after prolonged annealing, the spent ore coming from the furnace responded to the magnet. It could actually be taken out by means of a magnet. Actually, the iron was reduced from the ore during the whiteheart process, but with the blackheart process there was no reduction at all; there was merely a conversion of the carbon into another form.

The Wet Process of Core Removal, Casting Cleaning and Sand Reclamation

By R. WEBSTER

Removing sand, particularly core sand, by water pressure from grey iron and steel castings has been tempting to the American foundrymen for more than twenty years. The General Electric Company put in a castings washing plant at Erie, Penn., before 1920. It was, in general, an adaptation of hydraulic mining. Several hundred gallons of water per minute were discharged from a nozzle mounted on a fixed support and ejected at a pressure of between 300 and 400 lbs. Frequently, the castings themselves were put on a turntable, so that various sides could be cleaned conveniently. The gaggers were, in general, caught by a grating, and the water and sand resulting from the operation led into a succession of settling tanks, the first of which collected the coarser material, and the final one of the succession of three or four, containing, in theory, very small amounts of solids. This system has proved satisfactory where the cores are relatively soft and are easily accessible. A centrifugal pump, usually of three stages, is in general use for providing the water pressure.

It is obvious that a nozzle mounted in the wall of a large cleaning cabinet cannot reach into undercut cores. In this type of water cleaning method, also, it has been found necessary to put roofs over the cleaning room, which can be drawn back to facilitate the loading of large castings directly by crane. The roof is necessary for several reasons, the most important of which is that the large amounts of water thrown against the cores cause large pieces of core material and the gaggers to be thrown violently against the walls of the room, and might easily throw them over the walls if they were not roofed in.

The sand collected in the settling tanks is generally disposed of by taking the covers from the tops of the tanks and getting out the sand by a grab bucket, and the more or less dirty water re-used in the pump.

At the Allis-Chalmers Company, Milwaukee (which is the classical plant of this type, though not the earliest), approximately 50 tons of sand are disposed of each day by this method. Smaller castings are put in baskets, and put on a turntable for core removal. There are, to personal knowledge, only two steel foundries which use this low pressure system, and perhaps more than a dozen grey iron foundries making open work.

The chief criticism of the plant is a high first cost, and that complicated castings cannot be treated satisfactorily by this method.

A German Attempt

A second type of approach to the problem was made by the Badische Maschinenfabrik A.-G., of Durlach, where a high pressure pump ejected relatively small quantities of water at about 1,200 lbs. per sq. in., through a long nozzle mounted in the wall of the cleaning room, and operated from the outside. This elongated nozzle or lance was operated in a gimbal, which permitted a limited movement from the edge of the wall in a clockwise or anti-clockwise direction, and which might be advanced or withdrawn in order to bring the high pressure jet nearer to the core.

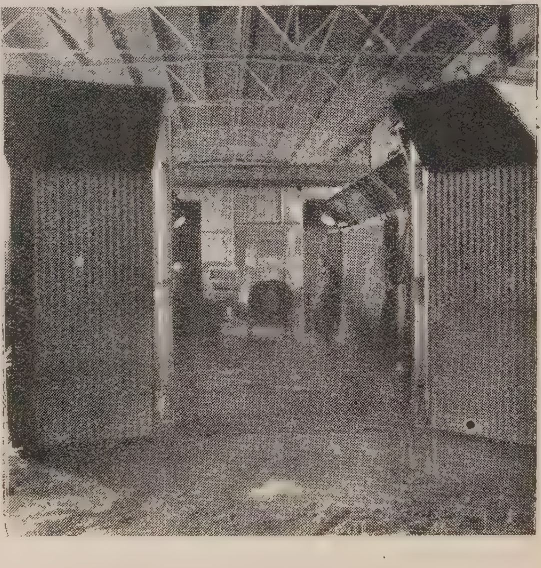


FIG. 1.—A TYPICAL HYDRO-BLAST OPERATING ROOM.

One of their reported difficulties was that they attempted to re-use water through the high-pressure pump in a continuous circulating system. Pump maintenance was, of course, extremely high. Relatively large savings in labour hours were reported. The author has seen no record of any further plants of this design going in.

An Unfortunate Failure

An ambitious attempt at water cleaning and water washing of sand by the low-pressure system was attempted near St. Louis by a large steel company, in which nozzles were mounted on overhead cranes to knock out very large cores on locomotive bed frames. These castings were up to 80 ft. long. The sand from the cores was carried by spiral conveyors to a rake classifier to eliminate the fine material, and was then passed on to continuous centrifugal machines of the basket type. This plant operated for about two years, and has probably done more dis-service to the wet casting-cleaning method than any other attempt, because the process was discontinued as being unsatisfactory.

The chief fault in this installation was not in the knocking out of cores, but in the handling of wet abrasive material. No accurate control of grain sizes of sand could be maintained. The centrifugal machines had a very high maintenance cost, and, unless they were continually serviced, failed to dry the sand to a moisture content desirable in the foundry. In theory, a centrifugal machine capable of continuous discharge rather than batch discharge, would be ideal for this service, but, so far as the centrifuge has been developed in America, the engineering, metallurgical and mechanical difficulties have been too great.

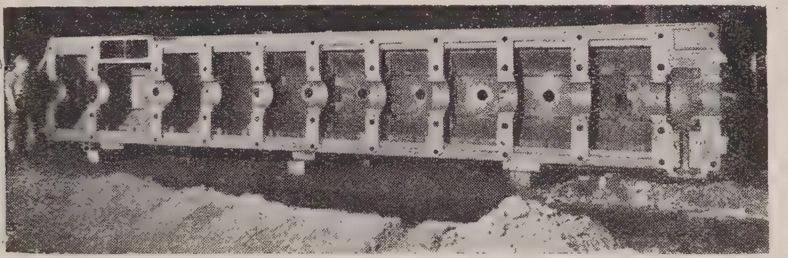


FIG. 2.—A 20-TON OIL ENGINE CASTING WHICH REQUIRED 116 HRS. TO CLEAN, BUT IS NOW FETTLED BY THE HYDRO-BLAST SYSTEM IN 16 MAN-HRS.

The Hydro-Blast System

Six or seven years intervened between these attempts, and the concept of the hydro-blast system (water sand-blasting) as now presented. The particular interest, from an engineering aspect, of the present hydro-blast system, is that this wet sand-blasting method sucks sand at a rather low velocity into a small gun, and ejects it in a very limited space of about 4 in. through a replaceable nozzle, at a velocity of approximately 20,000 ft. per min. In the original development, a rubber compound was used for the nozzle. It was found that, where velocities exceeded 12,000 ft. per min., or pressures were in excess of 800 lbs., no rubber compound was economically possible. It was found, for example, that, although water at the rate of 25 imperial gallons per minute was passing through a rubber nozzle, the impulses of the high-pressure water over a wide range of frequency created a hysteresis in the internal sections of the rubber liner, which caused it to melt. At 1,200 lbs. pressure, even with slow impulses on a high water pressure line, the rubber liner would melt within 20 secs., and vulcanise itself to the brass or stainless-steel bushing which contained it.

In current practice a tungsten carbide liner, cast centrifugally, is used, and this will last, under most abrasives, between 250 and 800 hrs. On the basis of 250 hrs., the cost in the replacement nozzles is about 5 cents (say 3d.) per hr.

The above figures were arrived at indirectly by volumetric computation, and represent the speed at which the actual volumes of sand and water must go in order to be ejected from the guns. In the gun itself, the initial orifice is a little less than one-fifth of an inch. Using 25 galls. per min. at a pressure of 1,200 lbs. per sq. in., the back pressure of the gun is between 30 and 35 lbs. The sand running through this gun amounts to between 70 and 80 lbs. per min. This sand, as well as the sand removed from the cores, falls through a grating, is washed across a vibrating screen to eliminate the oversize, and the good sand together with all of the fine material is then pumped to an elutriator or classifier, in which an upward flow of water carries the fine material over a lip with the excess water, and permits the coarser material to drop through the bottom into a sand collecting tank, which serves as a source of abrasive, the excess of which overflows into some kind of de-watering or drying equipment, and may then be used for cores.

Sand Recovery Process

The principal advantages of such a system are that a very dirty operation is performed without making any dust; one man may do the work of five or six; the sand may be recovered in a washed and graded condition, and generally fit for cores and facing in proportions up to 90 per cent. of the sand now going to the dump. Bonding material is washed out by this process, which necessarily involves re-bonding, and fits particularly with synthetic sand methods.

It should be reiterated at this point that core sand or moulding sand when it is primarily silica is returned to the foundry as core sand or facing material. It may also be used to replace the use of new silica sand where practice requires such a condition for increasing permeability in the backing-up sand.

Bonding material, which is a pre-occupation of the foundrymen using synthetic sand, is really not a question of importance, because whatever bond value there may be in sand which goes to the dump is, of course, wasted as well as the sand. In one American steel foundry the company has knocked out an average of 4,000 tons of steel castings per month over a period of about 4 years; has washed, classified, and dried at the rate of 15 tons of sand per hr. in a continuous system; and at a cost per ton of sand, delivered to storage bins directly over the sand mixing machines, of less than 4s., as against a previous cost of new sand of almost 20s.

It may be pointed out that the wasting of sand will cost, under the best conditions, at least 1s. per short ton, and that in congested areas this may reach up to 4s. The silica sand may be washed, classified as to grain size and distribution, and dried, for less than the latter amount.

Surface Effect

The physical effect of water sand-blasting, as far as surface cleaning goes, is quite different from that obtained by either a shot-throwing machine or by air-borne shot. The effect is abrasive rather than cutting; the surface finish is much smoother; the water and sand stream has a searching effect, and will sometimes reveal defects which would not be observable if the casting were shot-blasted.

The process will not remove spots of penetration unless an uneconomical time is spent on the work. It is, however, practicable to clean metal surfaces, quite aside from knocking out cores, to a surgical cleanliness. In two instances in America these plants are being used to surface clean the interior of castings which cannot be made clean enough by any other method. One of the results of this type of casting cleaning is a great saving in machine-cutting tools. There are many instances where a tungsten or tantalum carbide tool runs into a grain of sand lying on the surface of a casting, which blunts the tool end, requiring a take-down of the machine, regrinding of the tool and re-setting of it in relation to the casting surface.

From American experience, tool life is very much increased by a use of this water sand-blast process. It is not to be unduly stressed, but it is worthy of consideration. The effect has been particularly noticed in the softer metals, where the embedment of abrasive cuts down machine tool life. It will probably be practicable also, in certain types of work, to eliminate a pickling process now required in the specifications for certain anti-aircraft gear housings, bushing, etc.

Dust Eliminated

The presence of dust is always disagreeable to foundrymen, because of its effect on both men and machines. A long series of studies has been made on dust removal by water. It has been found, in sampling air for its dust count, that a velocity of impingement as between minute dust particles and water, of at least 12,000 ft. per min. is necessary. Where lower velocities are used, the water will not wet out the minute particles, because it does not overcome the effect of surface tension. It is, therefore, believed at the moment that low-pressure water systems do not actually prevent the diffusion of the very fine air-borne dust, which is the principal medical worry of factory inspectors. It is probable that the pneumokonioses are attributable to silica in sizes below 15 microns. This Paper is necessarily very general. Any of the assertions may be challenged. Detailed data are available in Great Britain to bear out these statements through application to the proper authorities.

In conclusion, the author is particularly desirous of thanking the Institute of British Foundrymen and the British Cast Iron Research Association for affording an opportunity of addressing a gathering of British foundrymen.

REPORT OF MEETING

In opening the meeting, **MR. N. C. BLYTHE**, the Branch-President, said the members were pleased to welcome so distinguished an American industrialist as their guest to-day. Mr. Ronald Webster was a pioneer in the development of the water and sand method of cleaning castings. He was visiting this country as a guest of one of the Ministries to ascertain whether the system would prove useful in the solution of a problem connected with armaments.

MR. RONALD WEBSTER, before giving his talk, which was illustrated by lantern slides, said he brought greetings from the American Foundrymen's Association—a body which was deeply appreciative of the efforts the Institute was making to maintain the high standard of British technology.

MR. BLYTHE, in calling upon Mr. Webster to give his lecture, asked him to thank the American Foundrymen's Association and on his return to reciprocate the sentiments expressed.

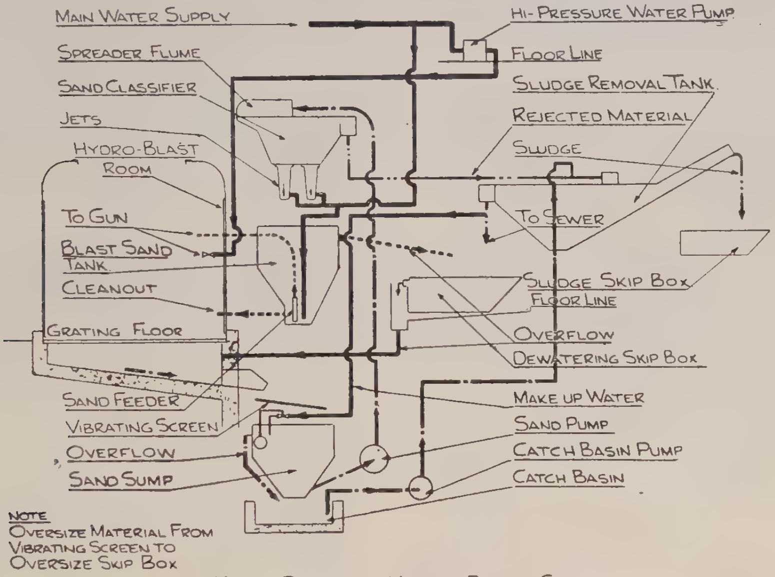
Vote of Thanks

MR. J. G. PEARCE (Director and Secretary of the British Cast Iron Research Association) proposed a vote of thanks to Mr. Webster, coupling with it an expression of satisfaction at the solidarity existing at this juncture "with our American friends." He said that it was three or four years ago since, in Chicago, he learnt something about the development which Mr. Webster had described. It had not then reached the stage of sand reclamation. While an installation for a given foundry could be discussed on a purely economic basis, the whole subject had been approached in a commendably scientific manner. There were other aspects which could not be judged on purely economic grounds. No one who visited a fettling shop could fail to be impressed with the desirability of dustless working from the point of view of the men working on the job. At present the industry was also faced with special aspects of the whole problem—the difficulty of transporting sand, both new and discarded sand; the problem of finding space in which to dump the discard, and so on. With that in mind, they in the Cast Iron Research Association had experimented with methods of reclaiming core sand, both dry and wet methods. He thought that anyone who had met Mr. Webster would pay tribute to his wide knowledge of this matter, and to his keen technical and scientific interest in it.

Mr. T. H. Gameson seconded the vote of thanks, which was accorded with applause.

DISCUSSION

Opening the discussion, Mr. F. J. Cook (past-President of the Institute) exhibited a slide of a very large casting, and asked whether the method of core cleaning described would be applicable to that particular instance. It seemed to him, he said, that in the case of a job of that kind, the process would have certain disadvantages in relation to the reclamation of the sand.



Flow Diagram Hydro-Blast System

In reply, Mr. Webster said that at a foundry he visited recently the core material was put on lorries, hauled out into the yard, riddled to get rid of the iron and then the sand, after being piled more or less mountain high, was removed either by a contractor, or in desperation was taken to a dump. The theory he acted on was that sand removal, as the cores were knocked out, must be continuous; that a convenient separation must be made of the iron and the brick bats, and that in many cases the saving involved would more than pay for the operation. He added that with one of the guns a man could do about what seven men did with pneumatic tools in knocking out internal cores. In every case where the plant had been put in the available floor space was increased.

Vision Maintenance

Mr. Everard said those with experience of fire fighting in respirators would be interested to know to what extent the operator's vision was interfered with by the helmet he wore. He also asked a question with regard to the use of water, which he said was expensive if the town supply was being used. He would like to know whether, if the settling system cleared the sand of silt and sludge satisfactorily, the overflow could be reintroduced into the supply on the suction side of the pump on the city main.

Practical Hints

Mr. Webster replied that in any blasting operation vision was always bad. They had designed a special helmet with a particularly wide angle of vision. A jet of water was run over the front of the glass to clear away any splashes or dirt which might interfere with vision. Incoming air kept the inside of the glass free from condensed water and also ventilated the rubber suit worn. The castings were generally illuminated by lamps set in the corners of the room. The operator would not be able to see whether he had removed everything, but if he knew the casting he would remove 95 or 96 per cent. of the sand before he had to examine it. Then the assistant whose job it was to get the castings in and out of the room came along with a torch and pointed out the spots which might have been missed. As to the second question, in America they had not found it practicable, so far, to free the water sufficiently of fine silica abrasive material to dare to put it through a high pressure pump. They used about 25 imperial galls. of water per min., and that water was wasted. They put in as little new water as possible, because the more new water they added and had to dispose of the higher the velocities that had to be contended with, which meant that they had to make a larger capacity sludge removal plant in order to prevent the uprising current in the tank from being too great. Therefore the whole purpose was to keep the amount of new water down to an economical point.

The Economic Minimum

MR. E. R. BRIGGS inquired whether plants had been put in where the firm was dealing with light automobile castings, not only iron but also aluminium and elektron. The speaker also wanted to know approximately what the output of a foundry must be before the plant described could be economically applied to its operations.

MR. WEBSTER replied that the question of cost depended to some extent on the nature of the work. If the work was complex, filled with small internal cores, a capacity of, maybe, 6 tons a day of either steel or grey-iron castings would do. In America, if the output of a foundry was about 8 or 10 tons a day—that was on the small side—they had to be sure that the nature of the work was such as to justify the capital expenditure. The rule has been thus far—and his firm had succeeded in making good on it with one exception—that it has repaid the cost of the equipment within two years. He did not like to undertake a job in the States where he could not show a probable saving within that period of time.

Nature of Reclaimed Sand

Answering the question whether, in the case of steel castings, sand reclaimed after the hydro-blasting process was in all respects equal to new sand, MR. WEBSTER said that grains which had been actually surrounded by hot metal would crack into finer particles. They would be removed in the final classification and wasted. Frequently, steel sands acquired a surface of very hard clay, and sometimes carbonaceous matter, which would lower the sintering point of the sand material. Mr. Webster quoted the experience of an American corporation, where the sand was used for cores and facing, and where, he said, it was claimed that the sand itself was more uniform than new sand. Rather less than one-fifth as many pattern changes were made than previously, because it was possible to control the shrinkage of the cores better with a washed and graded sand than with new sand. New sand varied slightly from load to load.

Jet Regulation

MR. J. W. GARDOM asked whether Mr. Webster recommended the use of the plant for the cleaning of annealed castings; further, was it applicable to castings of 30 or 40 lbs. in weight, steel castings particularly? Could the operator regulate the amount of sand or water coming out of the nozzle? Was the core sand cleaned of any bonding in it?

MR. WEBSTER replied that the practice was to make the core sand out of the moulding sand and lose all the bond. When the casting was pulled out of the box, there was usually sand adhering to it. If, basically, the sand was a silica sand, it would all go through, and the bond would be removed. He added that he had been attempting to establish some measure of cleanliness in sand. As he saw it, there were three ways of measuring the cleanliness of a silica sand. One was to compare a new, washed silica sand and a recovered washed silica sand having identical grain size and substantially the same grain shape, by adding a given quantity of oil or other bond and baking it under identical conditions, so getting a comparison of the tensile strength and permeability. If the silica sand, as recovered and washed, showed lower strength than the new sand, he considered that it was inadequately cleaned. It showed that there was a film on the sand which absorbed oil. There were two other methods. There was the loss on ignition—the actual loss of weight and the actual amount of gas evolved from the sand. On the recovered sand cores showed very little increase in the gas evolved over a new washed sand. They usually exhibited a higher tensile strength under the conditions of the oil bond test than with new sand, which was generally because there was some silt or organic matter remaining in the sand. This cut lower the sintering point. He did not trust the measurements of the sintering point. As to another point raised by Mr. Gardom, the operator could not regulate the amount of water thrown, but he could cut out the sand and throw pure water.

MR. J. G. PEARCE: With reference to cleaning sand, are we to take it that the cleaned sand, with the same amount of bonding material, is stronger and more permeable than the original sand?

MR. WEBSTER: Yes.

Reduction of Silicosis

MR. P. PRITCHARD referred to the problem of silicosis, and asked if Mr. Webster could give the meeting any information with respect to improvements effected in the matter.

MR. WEBSTER stated, in reply, that after the system had been in operation for a year, or six months even, the reduction in dust in the foundries was such that an abatement in insurance rates under the occupational disease heading was obtained.

Sand Casting of Brasses, Bronzes and P.M.G. Metal

By W. MACHIN, M.B.E. (Member)

Part A.—Some Causes of Defects in Brass and Bronze Castings

The manufacture of castings in the numerous brasses and bronzes for shipbuilding and engineering requirements to-day is an industry built upon the solid and dependable foundation of experience. A formidable task it would be to outline even those difficulties personally encountered over many years, more overwhelming to attempt to detail more than a fraction of the valuable information garnered by combined study, experiment, sometimes failure, and ultimate success. Where a standard type of casting is concerned, it may be said that successful production is, to a great extent, due to an established method built up by individual experience, or to one of generally accepted practice, but the constantly changing nature of modern requirements repeatedly introduces new problems for solution.

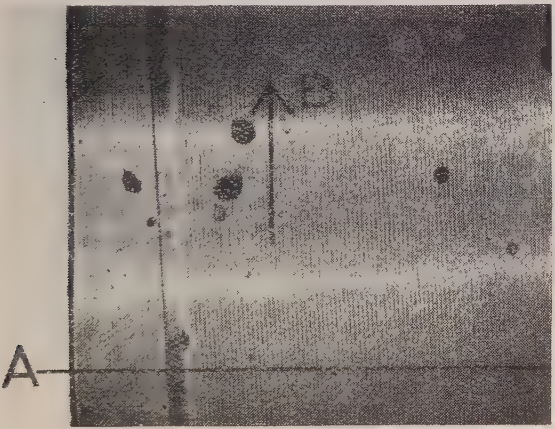


Fig. 1.—Defective Portion of Gunmetal Liner.

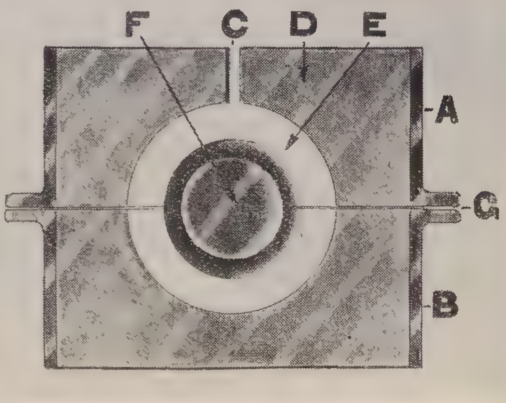


Fig. 2.—Method of Moulding the Same Liner.

Each phase in the making of a mould must be carefully considered in the light of results already obtained, and it may be assumed that the greater proportion of defectives are caused by the workman overlooking some small but important detail of procedure.

The composition, temperature and treatment of the metal are to be taken into account, factors which, accepted in their true perspective, are of the greatest importance in the production of a sound casting. The technique of metal melting has been comprehensively dealt with frequently, and it is, therefore, not necessary to refer at length to that aspect in connection with this Paper; it is intended to deal with the practical side, in outlining some of the causes of defects in brass and bronze castings. Prominent among hundreds of non-ferrous metals at present in use are gunmetal, and what is known in the foundry as manganese bronze, and it is intended to deal with rejects and replacements in these alloys as well as others, all of which are related in so far as the moulding and other operations in the foundry are concerned.

Defects due to Moulding Faults

Foundrymen cannot guarantee to produce 100 per cent. good castings, so the question of some castings rejected as a result of defects brought about by faults in the moulding technique will be covered. It is appreciated that ideas may differ substantially on many of the points raised, and in putting forward this Paper it will be understood that actual experience is represented involving altered method and the results obtained. In many instances, even after alterations have been made to moulds, and success attained, further similar castings have been rejected, the reason in almost every case being that a small but important detail in the moulding technique has been overlooked.

More castings are defective, and a correspondingly greater proportion rejected, through faults in the mould, and cores, than are given attention from the angle of troubles associated with melting. Whilst melting is of paramount importance in castings production, the purpose of this Paper is to stress particularly a few of the points in technique which the moulder does sometimes regard as unimportant.

Effect of Moist Material

The mould for the casting shown in Fig. 1 was cast horizontally. The mould joint was as indicated at A, and the defect was caused through moisture from damp material, *i.e.*, moisture from loam used for stopping in the joint between the two halves of the moulding box having been drawn into the mould. The mould was made by a competent workman; a perfectly vented core was placed in position and the mould closed, everything being apparently in perfect condition for the production of a sound casting. The casting was produced, and, during machining, defects were discovered as shown in Fig. 1.

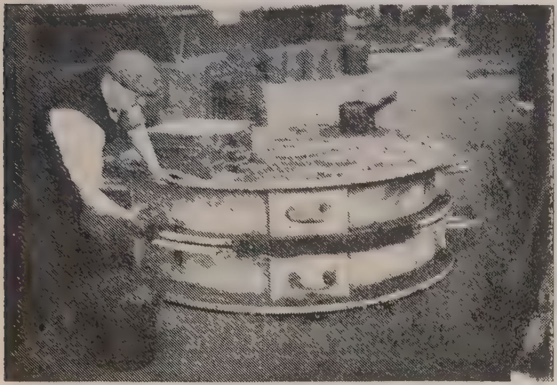


FIG. 3.—STOPPING UP THE JOINTS OF A DRY SAND MOULD.

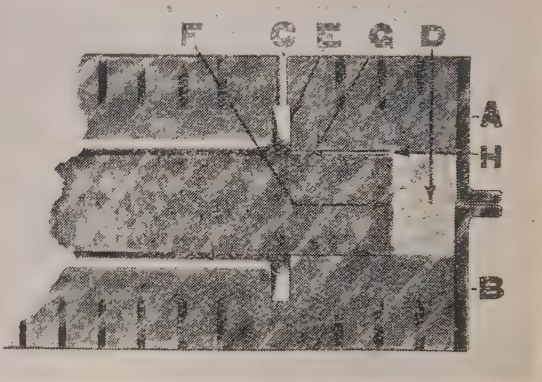


FIG. 4.—SHOWING END OF CORE RAMMED WITH SAND.

Before the next mould was put in hand close examination was given to the method employed in the manufacture of the defective liner, and the sources of the trouble were revealed. A and B of Fig. 2 show the upper and lower halves of the mould, C the riser, D the sand, E the casting cavity, F the core, and G the joint between the two halves of the mould. The gap G between the two parts of the moulding box had been stopped up with damp material in the form of loam, with the object of preventing the escape of molten metal. At C in this instance, as in numerous others, the riser in the upper half of the mould acts as a chimney, and the steam generated by the warm mould from the moist loam is drawn through the joint from gap G.

Reverting to Fig. 1, it will be noted that the blowholes are actually in line with the riser, as indicated by the direction of arrow B, thus establishing that the defect has been due to the presence of steam in the mould at this part. This unsatisfactory method has been the cause of this defect in numerous instances, there being no real need to stop up joints in this manner. Providing the two halves of the mould are securely fastened together to prevent lift during the casting operation, the metal will not leave the mould if the joint is not disturbed during the casting operation.

In Fig. 3 loam heavily loaded with moisture is

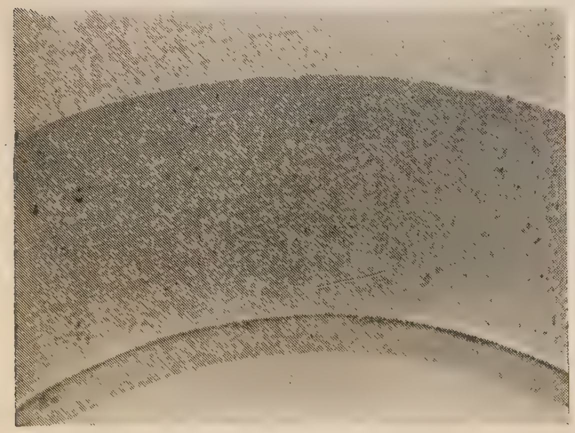


FIG. 5.—PORTION OF CASTING SHOWING BLOWHOLES ON MACHINED FACE.

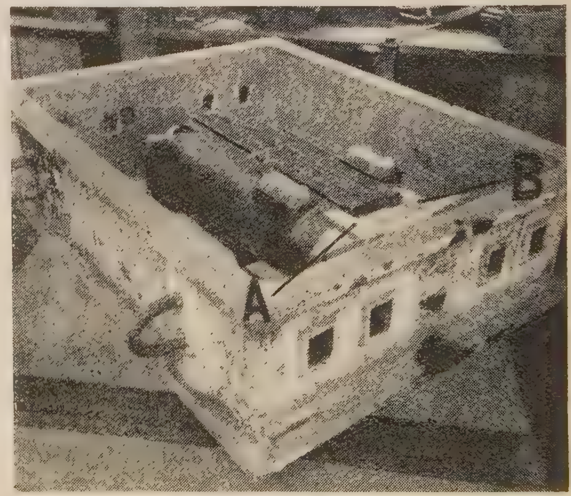


FIG. 6.—PATTERN IN POSITION READY FOR MACHINE MOULDING.

shown being thrown into cavity G, Fig. 2, between the top and lower half of the mould. The moulder's intention, obviously for safety purposes, is to prevent risk of the metal escaping through the joint. It is undoubtedly certain that a large percentage of bad castings is the outcome of this unnecessary procedure. Very similar trouble can be experienced in dry-sand moulds where moist stamping material may not have been thoroughly dried around the end of the cores.

In Fig. 4, F shows the end of the core, D the cavity between the core and moulding box, and E the casting cavity. The sand rammed in cavity D holds moisture which can be drawn through joint H by the assistance of suction from riser C acting as a chimney. A better method would be to use a thin loam stamp at position G, making certain that the same be properly dried before the top half of the mould A is placed in position. Under these conditions the two halves of the moulding box A and B must be securely fastened together to prevent strain during the casting operation, otherwise leakage of metal may occur through the joint of the mould G illustrated in Fig. 2.

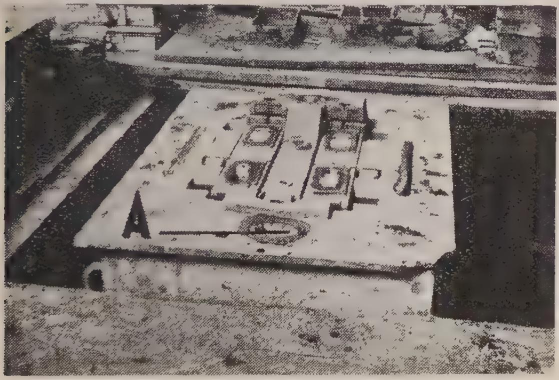


FIG. 7.—THE DOWN RUNNER.

In a busy foundry making many different types and classes of castings foundrymen are aware of the varying temperatures at which different moulds are cast. If portions of the mould or cores have been lying about for a few days after being dried, and, therefore, are cold when closed, care should be taken that moisture has not been picked up, otherwise such condition may cause the defect known as porosity (Fig. 5).

It will be noted that the small holes are general—quite different from those shown in Fig. 1, which are local. In many cases under observation, incorrect melting has been blamed for this defect, but it has been proved that it has been due to the presence of moisture.

Scabbing

Another type of defect which has given serious trouble is that known as scabbing, which brings about the appearance of sand on faces to be machined which are cast uppermost in the mould. This is due to sand becoming loose from the face of the mould, or core, and floating on the top of the metal during the casting operation. The sand becomes trapped in some projection, ledge, etc., in the mould or cores, and remains there. This type of defect can usually be found before the casting leaves the dressing shop, as the scab is easy to see if the casting is examined after being cleaned, and before any dressing or chipping is carried out. Scabs can also be caused by faults other than the presence of moisture, *i.e.*, unsuitable sand for the particular mould or cores, or insufficient venting.

In general, however, defects from scabbing are not nearly so frequent as those due to the presence of moisture. Those instanced cause the same defects to appear in other non-ferrous castings made from manganese bronze, phosphor bronze, yellow brasses, nickel bronzes, and silicon alloys. In addition there are also defects which can be definitely traced to the slow running of the mould, and, perhaps, also to feeders which have been put in unsuitable positions.

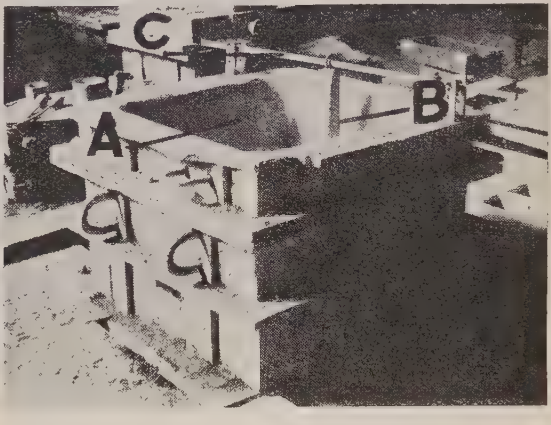


FIG. 8.—THE RUNNER BASIN.

Fast Running Essential

In all these classes of castings fast running is considered essential for the realisation of good results. It has been observed that many defects found in manganese bronze castings are the results of slow running, evidenced by subsequent leakage on pressure test and/or spongy patches in the areas most remote from the inlet to the mould, or from the main runners connected to the basin. The correct method, in the author's opinion, for casting manganese bronze is as illustrated in Fig. 6, *et seq.*

In Fig. 6 the inlets to the mould are marked A and B, and through these inlets passes all the metal required to fill the mould on its under part "as-cast." It will be noted that the runners are placed in such positions that the two separate streams of metal are travelling in the same direction.

The down runner on the joint of the mould is shown at A (Fig. 7); thus, this connected to a cross runner in the bottom of the mould feeds the two streams shown at A and B in Fig. 6. The one down runner is continued in a straight line through the top half of the mould, and is coupled up to the runner basin.

The runner basin A (Fig. 8) is large enough to take the whole of the metal required to fill the mould, and plug B prevents any metal entering the mould during the operation of filling the basin. It will be noted that the plug B is securely fastened by means of a bar C through the top of plug B. This is to prevent the plug lifting whilst the metal is being poured into the basin.

Fig. 9 shows the basin at A full of metal, and the two moulders are seen ready to lift the plug and allow the metal to run into the mould. It will be appreciated that immediately the plug is removed the whole of the metal will be transferred into the mould at a high speed.

In Fig. 10 the plug A can be seen lifted from the inlet to the mould, thus releasing the metal from the basin. It will be observed that no ladle is in attendance during this cast, the operation being carried out smoothly and without any flurry, which is desirable to ensure that every detail of the casting technique is correct. Under these conditions the running method is under more perfect control than would be the case with a ladle and a small basin. With the latter condition the speed of casting is controlled by the human element, *i.e.*, by the man who is operating the ladle, and in many observed cases the basin has not been kept full, with the result that the speed of casting has been too slow. In the former case, the method is foolproof as the runners are always full.

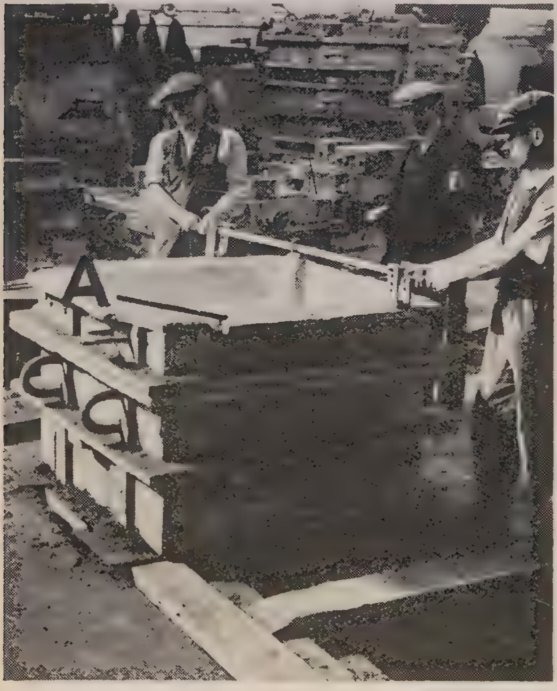


FIG. 9.—THE RUNNER BASIN READY FOR THE CAST.

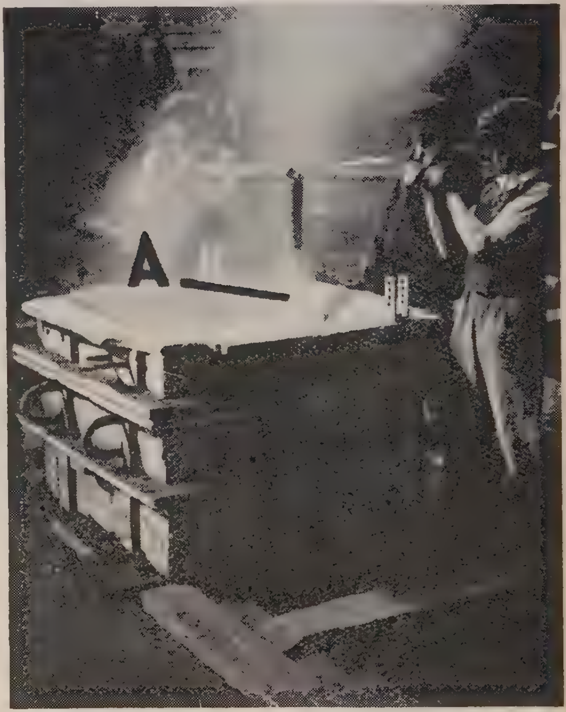


FIG. 10.—THE CASTING OPERATION.

Importance of Clear Vents

It is sometimes stated that this high speed of casting is risky owing to the possibility that the large number of cores, sometimes used in the make-up of the completed mould, may be moved out of position by the additional pressure, due to fast running. Thus, clear vents from all these cores are essential, it being very important to control this factor, otherwise poor results are certain. In Fig. 11 the vents in the cores are clearly illustrated, one of which is marked A, and these vents should be carefully connected from one to another during the time the cores are being assembled, to form the completed core (Fig. 12). This core can be seen placed in position in Fig. 7, and care should be taken to see that the vents are correctly sealed when being connected together, so that no metal leakage occurs into them.

The feeders and runner inlets are shown in Fig. 13 at A and B. The down runner connecting to the runner inlets and to the basin can be seen at C. It will be noted that all the feeders and runners have been cut away.

High-Strength Manganese Brass Casting

The casting shown in Fig. 15 is made in high-strength manganese brass, had to withstand a very high liquid pressure, and also gave trouble with slow running methods. It is one of the highest quality, and, therefore, is a good comparison for discussion as regards fast and slow running methods. The argument for slow running this casting was that a disturbance took place in the metal when run fast which caused zinc oxide to be seen on the skin of the casting. A casting was made under the slow pouring method and it leaked very badly under hydraulic pressure. The method was altered after this experience, coupled with the fast running method introduced, gave perfect results. The job was cast in a vertical position, using both slow and fast methods, and in Fig. 15 the mould will be seen with the core in position. The runner is shown at A and the feeder at B, with four inlets from down runner

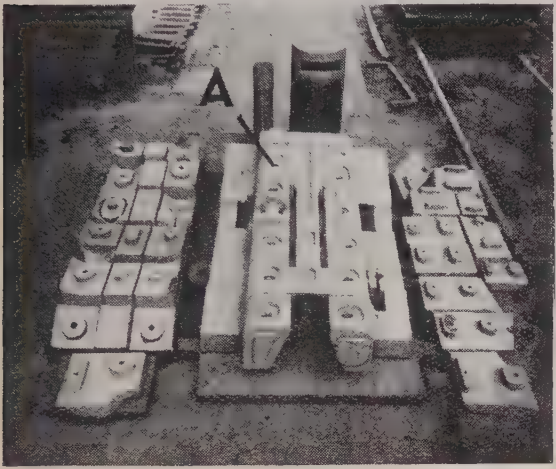


FIG. 11.—THE LARGE NUMBER OF CORES USED IN THE JOB.

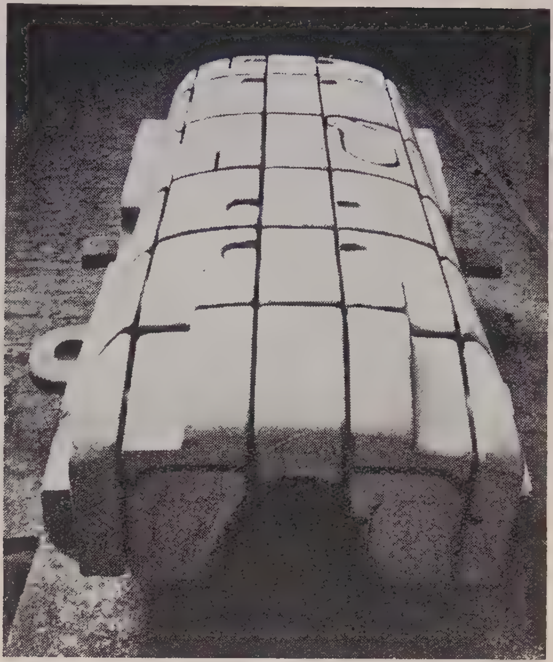


FIG. 12.—THE COMPLETE ASSEMBLED CORE.

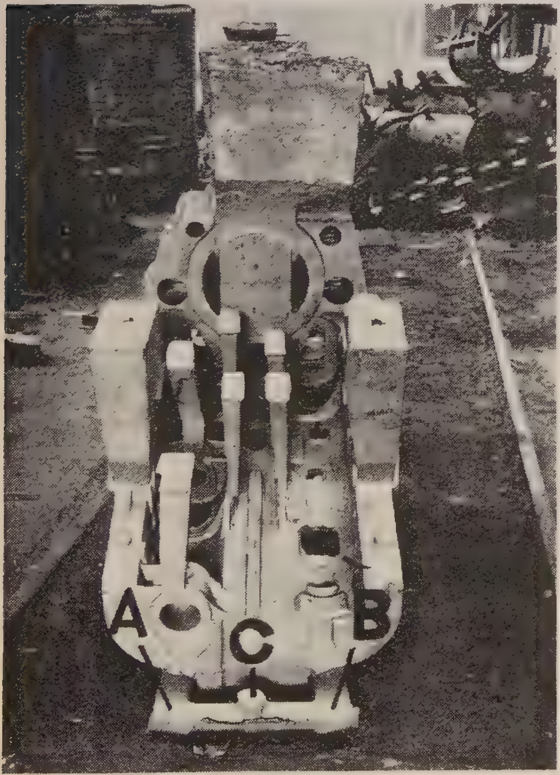


FIG. 13.—THE CASTING.

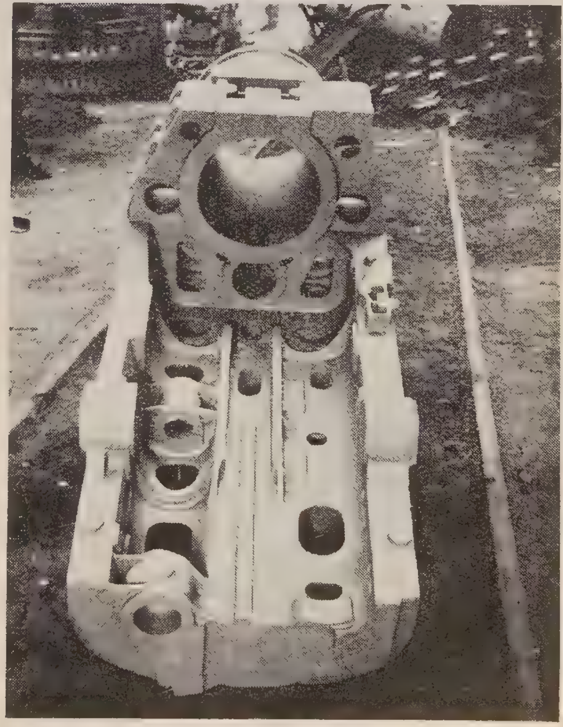


FIG. 14.—THE FINISHED CASTING READY FOR MACHINING.

at C. The completed mould with large runner basin fitted is shown in Fig. 16. The basin is at A with plug B attached to runner A, shown in Fig. 15. The total quantity of metal required to cast the job is poured into basin A before plug B is drawn, allowing the job to be completely cast from the basin after the ladle has left the job.

In Fig. 17 the feeder is shown at A and the runner at B, and the casting surface was definitely clearer of oxide defects than on the one cast under the slow running method. The metal at the cut (Fig. 18) showed up perfectly solidly after removal of feeder.

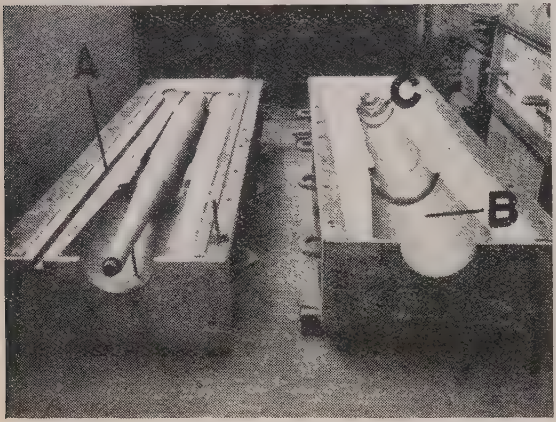


FIG. 15.—ANOTHER TYPE OF CASTING.

This result should clearly prove that the fast method of running high zinc alloys is definitely better than the slow method. There is no doubt that very much less zinc oxide is accumulated by running under the fast method, and, in addition, hotter metal is obtained in the feeders after the casting operation is completed, thereby allowing the casting to be better fed. It will be gathered from the foregoing that both gunmetal and manganese bronze are better cast fast to obtain good results. With all other conditions correct, this is certainly the case. Slow running conditions, in the author's opinion, are definitely incorrect.

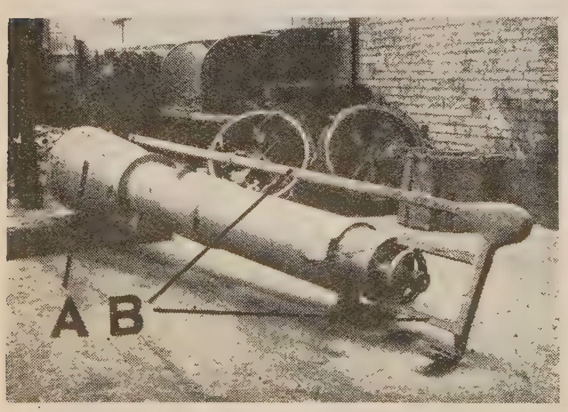


FIG. 17.—THE CASTING WITH RUNNERS AND FEEDERS ATTACHED.

Dressed Scabs Revealed by Machining

It has been mentioned that scabs on castings cause serious trouble when they occur, and that this defect is easily seen before the casting leaves the dressing shop, or before they are machined. One such case occurred on a few large phosphor-bronze wheels obtained from an outside source on which this defect was present, and the castings were delivered without any comment, after the scabs had been dressed away.

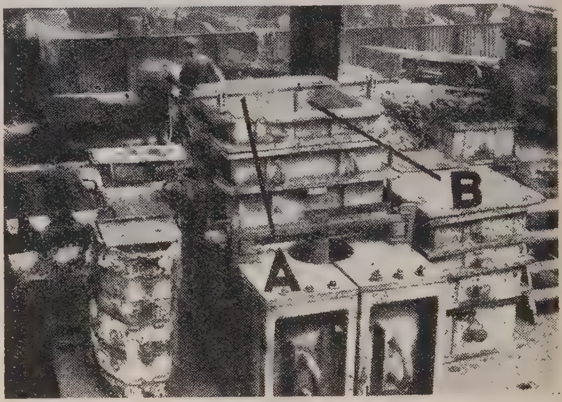


FIG. 16.—THE COMPLETED MOULD WITH LARGE RUNNER BASIN.

The defect, of course, was not observed by the machine-shop personnel. After machining, sand was seen on the finished faces on the wheels, and the machine-shop examiner notified the foundry staff. When the items were examined by the latter, scabs were seen on the black faces of the castings. They are shown at A, Fig. 19.

This item caused much unnecessary cost, because the machining was practically finished before the sand from the scabs commenced to show up on a very important face of the casting. The castings,

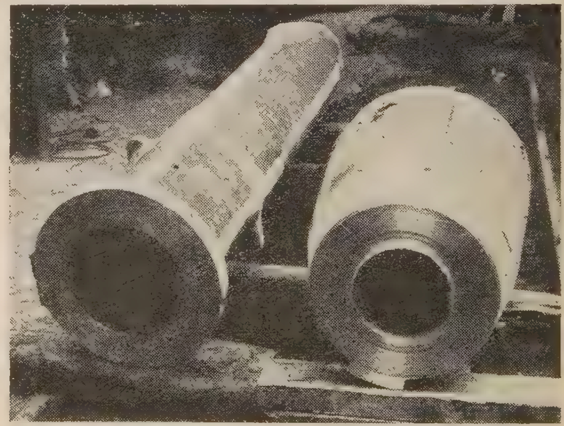


FIG. 18.—THE CASTING WITH FEEDER CUT AWAY.

which were all rejected and had to be replaced, should really have been scrapped after the dressing-shop examination. In some cases, instances similar to that one just described are allowed to proceed by the foundry staff, *i.e.*, on castings which are not machined practically all over.

It must be pointed out that castings of importance should not be allowed to leave the foundry in this condition, because serious faults in service can occur through this type of defect. The loose sand from a defect of this kind can become deposited in a vital part of a very important unit of a gun, engine, etc., and may cause serious breakdown, with danger to life.

The loose sand may not show up on a finished machined casting, and it may therefore pass into service, but it may be the means of weakening a rib or other important part. The defect on the wheels was pointed out to the foundry which made them, and steps were taken to eliminate the trouble, after which the replace castings were quite satisfactory. The investigation of this defect revealed the trouble to be due to the moulds having been made under a new process, and it is not possible to say how the matter was overcome, only that the moulds for the replacements may have been made using different moulding materials.

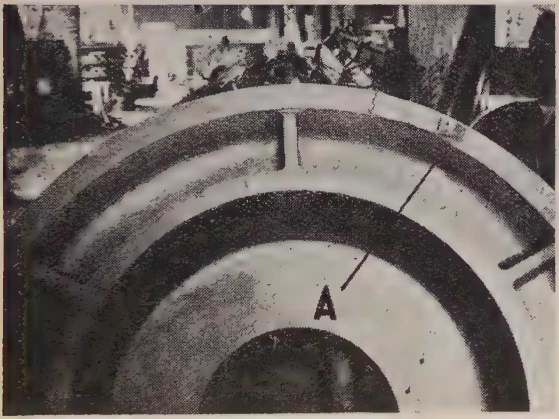


FIG. 19.—THE SCABS ARE SHOWN AT " A."

Defective Core Vents cause Blowholes

Another cause of blowholes or porous defect may be brought about by vents from cores not being taken away to atmosphere at the correct position. This defect sometimes shows up in the examination of the castings in the dressing shop, but more often the defects do not show up until the castings are machined, or pressure tested. The defect usually takes the form of that seen in Fig. 1, or porosity similar to that shown in Fig. 5. The practised eye can usually see the cause of this trouble at a first glance, and immediate steps are taken to effect an improvement. This mainly consists in altering the position of the vent holes from the bottom, or side of the mould, to the top, which invariably cures the trouble. The size of the core, and vent, is an important factor to take into account, there being no fixed rule for guidance. The matter is left to an executive, who usually arranges for a large enough core to meet all that is required to take away the vent correctly. The main cause of the trouble appears to be due to position of the vent, and not its size, and an explanation to make this point clear may be of some value.

The job shown in Fig. 20 is cast with face A in the top of the mould, and face B in the bottom of the mould, both the faces being machined when the casting is ready for assembly. In the design it was arranged to have holes in the casting at D and D1 to fix the core in correct position, and later to remove it from the casting. The holes at D1 were used by the moulder to bring away the vent. It will be seen that the holes at D1 are in a position well removed from the top of the core, and in this position a pocket of air exists in the space H above this hole.

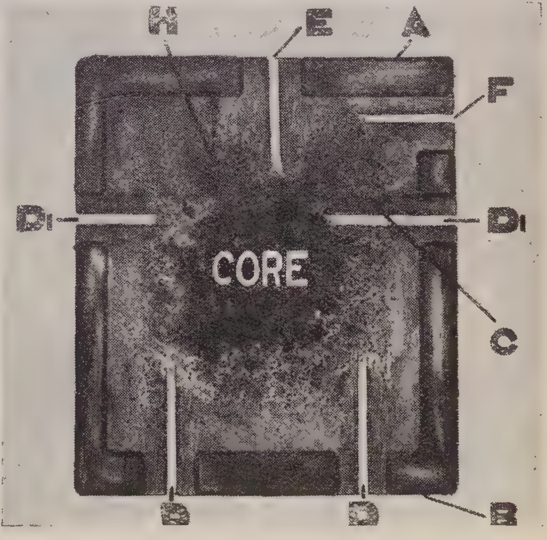


FIG. 20.—SECTION OF PLAIN BOX CASTING.

The position of this vent hole D1 is not good foundry practice, although there are many who will continue to use such a position. Many designers of castings are not aware of this technical point and, therefore, would not give it their consideration. They are most concerned with allowing sufficient holes through which to remove the cores from the casting. It has been mentioned that position D1 is incorrect for this purpose, so it is suggested that these holes should be moved to either position E or F. The foundrymen must discuss the proposed alteration with the drawing office when permission is generally given to proceed, so as to get the foundryman's results correct in this connection. The two new suggested positions E and F, it will be seen, are each on the top of the core, but E is considered better than F because it is directly over the top of the core, whereas F is at the side, but even so F in this position is considered better for vent purposes than the D1 position.

Further Examples of Improved Venting

A further example is shown in Fig. 21. The top of the mould in this instance is as shown on the section at A where the defective part was seen. The vent was taken away at B, which is again below the top of the casting and leaves a pocket of air at C. The alteration to improve this defect was made by adding a core hole at D, which enabled the moulder to release the air in the correct place, *i.e.*, from the top of the core.

Another case is shown in Fig. 22. This casting for some important units was recently made in high-strength manganese brass. The pressure test on this casting was 8,000 lbs. per sq. in., and it will be appreciated perfection is necessary in the quality of the casting to withstand this pressure. The section at A must be fed to obtain this result, so that end was cast uppermost to allow of a full size feeder being added at B. The designers would not allow a hole in the end to take away the vent from the main core, so one casting was made for trial with a core inserted. It will be seen that the air in this instance must all travel through the lower part of the mould, *i.e.*, the outlet would be in the direction of the line to C. The casting of this component was carefully controlled, and although the core was made under perfect conditions as regards venting, etc., the metal would not lie quietly over the top of the core during the casting operation.

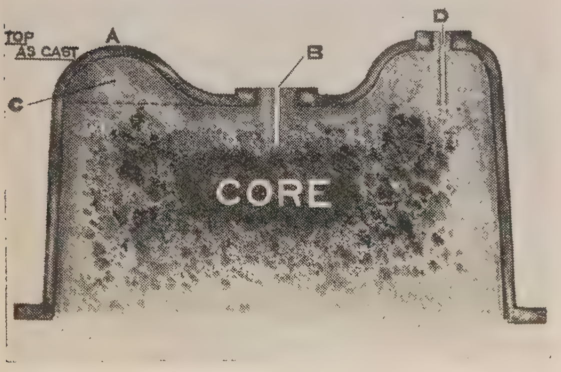


FIG. 21.—SECTION OF PRESSURE CASTING.

The casting was machined and turned out defective, spongy metal being seen in a line round the diameter on a level with the top of the core on the outside diameter shown at D. The casting was rejected and the remainder were cast solid and proved satisfactory. The shrinkage of this metal is extensive, being very similar to steel; the feeder from one of the solid rams was sectioned for examination, as shown in Fig. 23.

The shrinkage shown at A will give an idea why section A in Fig. 22 was selected to be the part requiring the feed so as to obtain the good casting required to hold the high pressure asked for by the designers in the finished article. Reverting to Fig. 5, showing blowholes on a machined face of a piece of metal cut from a casting, this defect has on many occasions been called porosity. In a number of cases which have been described this type of defect has also been blamed to incorrect melting.

Oxide Inclusions and Oxidation

In some instances the trouble has also been ascribed to what is called oxide inclusions, which can, of course, be caused by incorrect melting. On the other hand, one hardly ever hears a foreman moulder say that the fault is associated with one or other of the causes which have been described, *i.e.*, moisture in the mould or a bad vent from a core. There is a feeling with some foundrymen that small amounts of moisture in a mould do not matter much, but such a condition in dry sand moulds for non-ferrous castings, is considered fatal to good results. In this connection, therefore, it will be observed that it is important to obtain a true history of the manufacture of a mould from which a bad casting has been produced before a replace mould is made. By so doing the fault in the first mould can be properly dealt with.

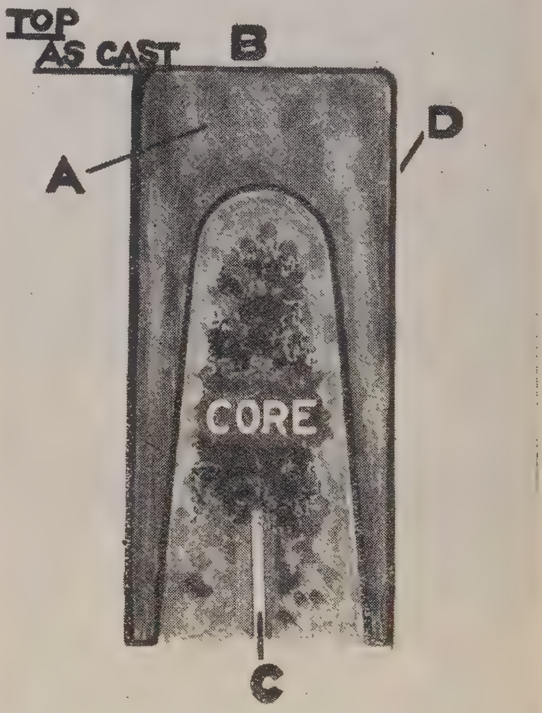


FIG. 22.—SECTION OF HYDRAULIC RAM.

It has been mentioned that the cause of the defect shown in Fig. 5 may be assigned to oxidation which has taken place during the melting of the metal. This fault is understood to mean that one or more of the elements in the alloy or alloys have combined with oxygen. This reaction can take place to a large extent at high temperatures, therefore the amount of oxide formed is in proportion to the degree of temperature of the metal when exposed to atmosphere. It can, without doubt, be said that oxides will be created much faster at high melting temperatures than with low. The prevention of oxidation is therefore extremely important and the temperatures at which metals are melted should consequently receive careful attention. The importance of this attention is essential because, for example, if there be tin oxide in a bronze, its tensile value decreases.

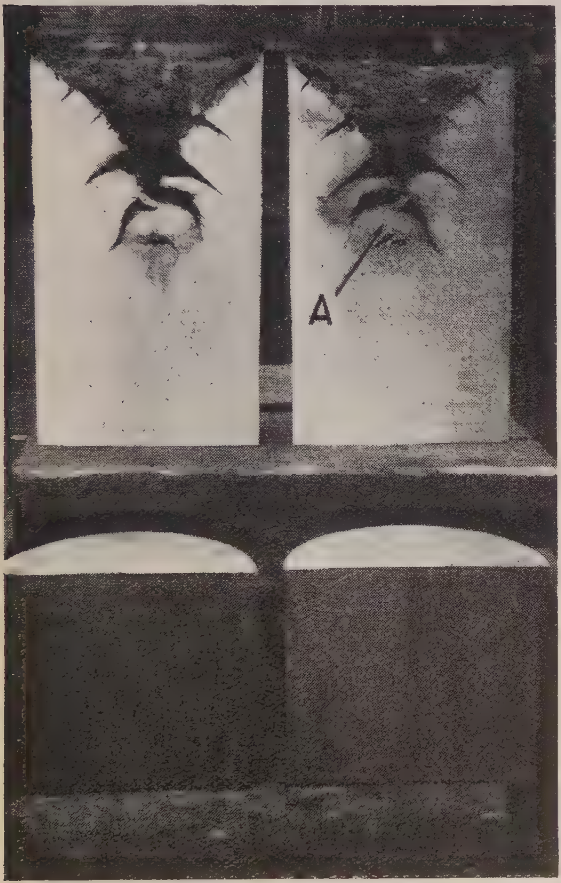


FIG. 23.—SECTION OF FEEDER.

The reason for this is that the oxide is a foreign body, therefore, heterogeneity of fracture is certain when oxide inclusions occur. In addition it will be appreciated that these inclusions cause a casting to be porous, which is quickly found when it is for an application where liquid pressure tests are specified; the reason for this is that the metal is in a condition similar to that shown in Fig. 5. It will be seen, therefore, how important it is that the melting practice used on any non-ferrous alloy should be as correct as possible.

Preventing Oxidation

One good method to prevent oxidation taking place is to keep the surface of all metals in liquid form well covered with either charcoal, glass or other suitable covering so as to prevent the oxygen in the air from combining with one or the other of the elements in the alloy. This method prevents oxidation considerably, but it is necessary to cover the metal in the early stages of the melt, *i.e.,* as soon as the solid charge commences to drip; it is not considered sufficient to cover the metal after all the elements have been melted.

It is thought that these remarks on melting practice may be considered as going over very old ground, but the advice is considered good, and the care of keeping the melt well covered will in the long run repay those who do so. On the other hand, however, it is considered that the few simple points raised connected with the moulding practice are the cause of more defective castin than is the case with bad melting practice.

Part B.—The Manufacture and Properties of P.M.G. Metal

P.M.G. metal in its various grades is a silicon iron copper alloy, the standard mixture containing 88 per cent. copper, 10 per cent. hardener and 2 per cent. zinc. It was intended, during its development, to replace ordinary gunmetal and similar bronzes. The letters P.M.G. which were used to name the metal are intended to mean a metal which would replace " P " phosphor bronze, " M " manganese bronze or brass, and " G " gunmetal.

The tensile strength values in a cast and forged condition are superior. As a bearing metal its application requires careful consideration when comparing it with results that have been obtained from phosphor bronze. P.M.G. metal has given excellent results in some applications as a bearing metal and also where friction exists in wheels which are heavily loaded. At the present time, when tin is causing us to switch over to another alloy or alloys, this metal will no doubt be used more extensively. In view of this and the long experience the author has had in its manufacture, he has thought that it would be advisable at this stage to give a short practical account of the methods of manufacture of the metal, also some technical advice as to its use in the production of castings.

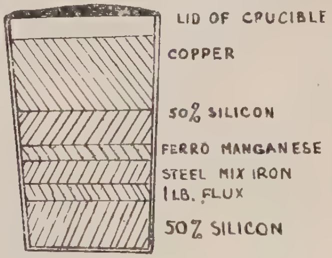


FIG. 1.—CRUCIBLE CHARGE FOR P.M.G. HARDENER.

Tests Results Available

It would be too tedious to recount all the various tests which have been carried out, and therefore it is proposed to leave much of this matter for inquiries from members. The author has records of many tests carried out by various firms in Great Britain, America, Germany, France and other countries and this knowledge can, if desired, be published from time to time in the "Foundry Trade Journal," or can be sent to any member making the metal who may require any information. The tests cover the mechanical properties of the alloys with varying percentages of zinc and copper and from 1 to 10 per cent. hardener. There are also tests from metal up to as much as 20 per cent. hardener in the mix, and others made at various casting temperatures from 950 to 1,300 deg. C. Test results when mixing 25 per cent. P.M.G. metal scrap, *i.e.*, heads and fins, and 75 per cent. P.M.G. metal borings taken from machined castings are also available.

There are also tests which have been carried out from green sand test-bars and dry sand test-bars, forged material at various temperatures, extruded bars, rolled sheet, compression tests, fatigue tests, torsion tests, shear tests, tests under various temperatures, corrosion, erosion, effective resistance to corrosive agents, and bearing tests. In addition there are figures for melting losses which have been carefully taken. The war effort to-day calls for the passing on of correct information amongst ourselves to enable production to be handled satisfactorily in all foundries. To withhold any information which will cause delay is playing into the enemies' hands.

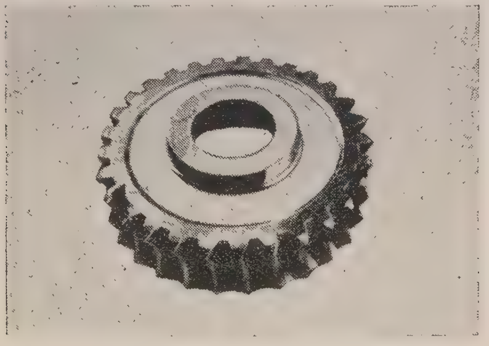


FIG. 2.—GEAR WHEEL BLANK IN ORDINARY P.M.G. METAL.

Nature of P.M.G. Hardener

The hardener for P.M.G. metal is a substitute for tin, and the alloys are thus manufactured with the hardener incorporated to replace the tin in the various bronzes which may be made so that, for example, 88 per cent. copper, 10 per cent. hardener and 2 per cent. zinc would replace gunmetal. The test results have been obtained under proper supervision and will be found to be superior with P.M.G. metal than is or ever was the case with gunmetal. In view of this the Admiralty, War Office or any other authority should have no difficulty in deciding whether it can usefully replace the well-known alloy containing 10 per cent. of tin. A personal view is that much of the tin which has been used in the past should have been eliminated years ago. The hardener* can be made without difficulty in a good refractory plumbago crucible. The components are copper; silicon; phoshor copper (15 per cent. phosphorus); ferro-manganese (75 per cent. Mn approximately); and a steel-mix iron (preferably of the Emmel type).

Preparation of Hardener

The melting or manufacture of the hardener is carried out in the following way: A 300-lb. crucible is used to melt 100 lbs. of the hardener; this is done to get in the complete charge (with the exception of the phosphor copper) at the one operation. When charging the crucible the order is, half the silicon, then 1 lb. of Cuprex flux, iron, ferro-manganese, second half of the silicon, then copper. The lid is then placed on the crucible top, the fire of the melting pit made up to the top of the crucible with coke, and the lid of the pit fire then put in place. The pit fires used are natural draft and it takes two hours to melt 100 lbs. of hardener. After 1¾ hr. in the fire the lid of the crucible is removed and the phosphor copper is added. After another ¼ hr., ½ lb. of Cuprex flux is added, the melt is stirred with clean iron rod, drawn, skimmed, and cast into ingots 9 in. long by 1½ in. thick. To make the question of the method of charging the hardener more clear, as this is considered a very important matter in the melting of same, Fig. 1 has been included.

FIG. 3.—P.M.G.-METAL WHEELS FOR CRANES, ETC.

The metal is allowed to cool in the ingot moulds, and afterwards taken into the metal store to be weighed and used exactly the same as tin. It is weighed out like tin to use in gunmetal, *i.e.*, 88 per cent. copper, 10 per cent. hardener and 2 per cent. zinc. After weighing it is charged exactly the same as gunmetal into a crucible and melted on the same lines, the zinc, of course, being added after the copper and hardener have been run down or melted. It will be found that the ingredients melt at about the same rate as gunmetal ingredients. In a good melting pit 300 lbs. of metal should be out of the fire in 45 mins. after charging the crucible.

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* This hardener is a patented alloy, the property of Vickers-Armstrong, Limited, Barrow-in-Furness.

Melting Procedure

No great care need be taken regarding the use of scrap, as 25 per cent. of P.M.G. metal scrap, 75 per cent. of P.M.G. metal borings from machined castings have given as much as 24 tons per sq. in. U.T.S. with 12 tons yield, and 21 per cent. elongation. These figures are the best that have been obtained from scrap melts, and they give an indication of the quality when using up scrap metal. It is essential for all the scrap to be P.M.G. metal; it must not be contaminated with gunmetal or phosphor bronze scrap, as these two alloys contain tin, and tin is fatal to good results. The reason for this is that tin will not mix with P.M.G. metal either in low or high percentages. As to the temperature at which it is considered best to cast P.M.G. metal, the following figures may be of interest:—

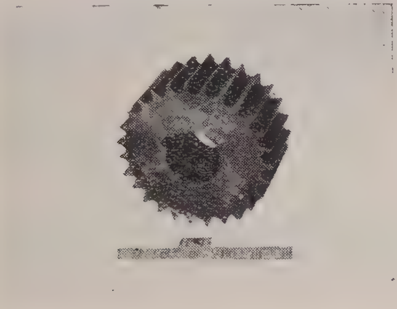

FIG. 4.—A GEAR WHEEL AFTER 10 MONTHS' SERVICE.

Casting Temperature.	U.T.S. Tons per sq. in.	Y.P. Tons per sq. in.	E. per cent. on 2 in.
Deg. C.			
1,300	23.2	11.2	16
1,140	23.2	10.8	19
1,100	24.4	11.2	20
1,050	25.2	12.4	21
1,000	18	12	4
950	16	12	3

It will be seen from the above figures that between 1,050 and 1,300 deg. C. will give the foundryman a very wide scope as regards thick and thin sections in a casting. He should from this information be able to pick out a temperature to cast his work successfully. The casting temperature figures detailed were carried out at a foundry in Belgium, and their correctness has been confirmed on many occasions in the foundry at Barrow.

Types of Castings Made

The very varied types of castings which have been made by brass moulders, used to the making of moulds for gunmetal work over a number of years, are well shown in Fig. 2, *et seq.* Fig. 2 shows a gear wheel blank made in ordinary P.M.G. metal with 10 per cent. hardener, which gave a continuous run of 50 hrs. of 97 r.p.m. run, with a forged steel worm, undergoing an estimated driving pressure of 3,760 lbs. on the teeth. Fig. 3 illustrates a further group of P.M.G. metal wheels for cranes and other applications, all of which have given excellent results in service.

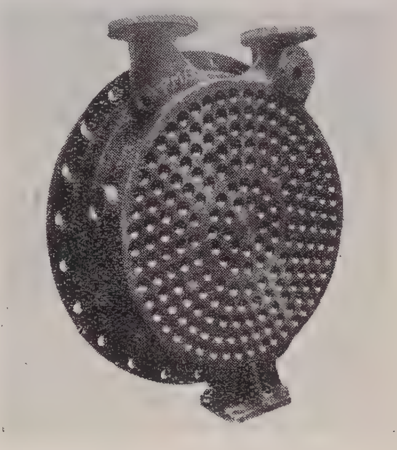

FIG. 5.—STEAM FEED HEATER.

In Fig. 4, one of the wheels after service is shown; this was put into use on a very heavily loaded crane and was worked for 10 months, double the period given by competing bronzes for the same purpose. It was dismantled after the above period, and the photograph well indicates the degree of resistance to fatigue.

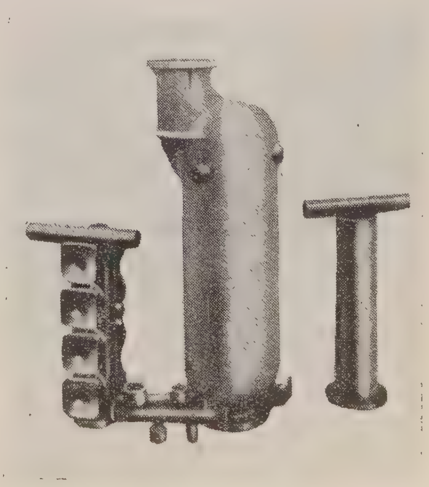

FIG. 6.—P.M.G. CASTINGS FOR INTERNAL-COMBUSTION ENGINES, ETC.

Fig. 5 shows a steam feed heater, the diameter of which is approximately 40 in. and the width is approximately 10 in. The water pressure applied to this casting was 600 lbs. per sq. in., and no leakage was traceable on this test. The perforated plate was cast solid, and the holes were drilled in it. This is obviously an intricate casting, and is a good example of testing the metal under liquid pressure.

Fig. 6 gives an indication of the variety of castings which have been produced in P.M.G. metal for internal combustion engines, marine engines, condenser work, etc. Macrostructures taken from sections of the castings are shown in Figs. 7 and 8. Many of these castings are guaranteed to resist water pressures up to 2,000 lbs. per sq. in. A further group of castings is shown in Fig. 9.

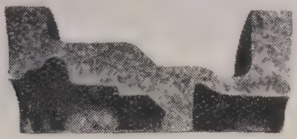

FIG. 7.—MACROSTRUCTURE OF ONE OF THE CASTINGS SHOWN IN FIG. 6.

Such castings as condenser doors, 8 ft. 6 in. long and $\frac{5}{16}$-in. wall section, feed regulator castings, and valve boxes for air compressors have been successfully made. In Fig. 10 chilled bush castings are shown.

Pressure-Resisting Results

It will be appreciated, after examining the variety of work illustrated, that the metal is one which can be used by the foundry to replace successfully gunmetal. In the author's opinion, 99 per cent. of the gunmetal castings which are being put into service to-day can be successfully made in this alloy.

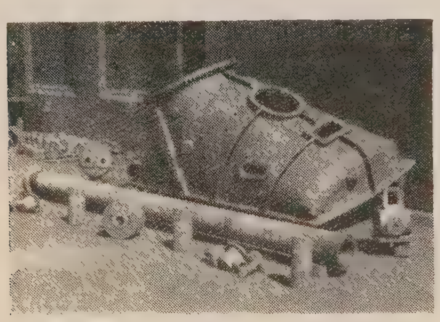

FIG. 9.—CASTINGS IN P.M.G. METAL.

As a further proof of this, fluid pressure tests have been carried out on a bush made in P.M.G. metal, and one made in gunmetal. The P.M.G. bush withstood a pressure of 6,000 lbs. per sq. in. without distortion, its size after machining being 10 in. long, 3-in. bore, and 3.75-in. outside diameter. The gunmetal cylinder of the same size, made from new metal run down and afterwards remelted, commenced distorting at 5,000 lbs. per sq. in. and fractured at 6,000 lbs., the length of the fracture being 0.2 in. The diameter of the bush in gunmetal after testing increased from 3.75 to 3.781 in., the bursting stress being 10.55 tons per sq. in.

The full details of these tests are available to members of the Institute.

Running Problems

The foundryman's job of deciding the best way to run and feed castings is not difficult, but a few notes on these technical matters may be of interest. In Fig. 11 is shown a tee piece, which would be run in one of the flanges, shown "A," with a feeder on the top of this flange, in which the runner is used. The position of the feeder is at "B." The metal cools somewhat during its passage through the mould, and it has been found in practice that it is only necessary to add a vent on each of the flanges shown at "C," the size of such vents being sufficient at about $\frac{1}{4}$ in. dia.

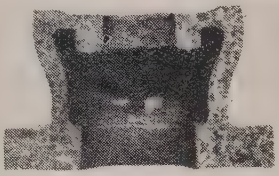

FIG. 8.—MACROSTRUCTURE OF ONE OF THE CASTINGS SHOWN IN FIG. 6.

Another casting section, shown in Fig. 12, is that for a stop valve. The runners in this case will be placed in one of the flanges, say at "A," with the feeder at "B." In each flange vents at "C" are used of the same type mentioned as for Fig. 11, that is, $\frac{1}{4}$ in. dia. For the casting shown in Fig. 13, which is a section of a four-way piece, the runner would be at "A," as in Figs. 11 and 12, the feeder placed at "B," and the vents, $\frac{1}{4}$ in. dia., placed from the top of each flange at "C."

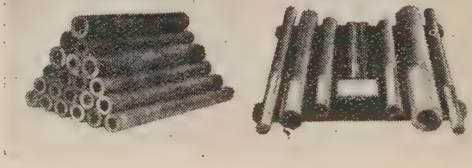

FIG. 10.—CHILLED BUSH CASTINGS.

These three technical cases give an indication to foundrymen concerning running and feeding. In the case of vents shown at "C," each case will be recognised by them as being used to release the air from the highest part of the casting. Castings of this character have been successfully manufactured up to 6 ft. in length. It is obviously not possible to give sizes of runners and risers in general, as all foundrymen know that this is only determined by the thickness of the casting and by the design. If, however, any advice is required on any particular casting the author will be pleased to help.

P.M.G. metal castings are very clean when removed from either green or dry sand moulds. The main reason for this is due to the fact that there is no tin in the alloy, as is the case in gunmetal. In view of this, there is no penetration into the sand as is sometimes the case with gunmetal. The metal sets very rapidly in green sand moulds, and castings can be stripped whilst red hot, and the metal will not scale in the atmosphere.

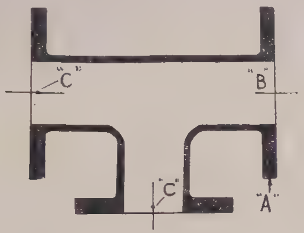

FIG. 11.—T-PIECE CASTING.

Regarding the question of sand used for manufacturing moulds and cores for P.M.G. metal to be cast in, it may be noted that any sand that is used for the manufacture of moulds for gunmetal and other non-ferrous alloys is satisfactory when faced with lithite or plumbago, dusted on in the case of green sand, and sprayed on in the case of dry sand moulds. This method will give good results, and the castings should show a very clean skin when stripped.

Contraction Problems

Contraction Allowance.—It has been found in practice that this is very close to gunmetal, that is between $\frac{1}{8}$ in. and $\frac{3}{16}$ in. per ft. Here again the type of job controls this matter to some extent, but if the practice be followed as for gunmetal good results should be obtained. As to the important question of contraction of castings made in silicon bronze, it has been found that P.M.G. metal contraction operates at a much greater speed than is the case with bronzes containing tin. In cases of castings which are made in this alloy and are fairly long, made in dry sand moulds, care should be taken to allow the casting to shorten by slackening or easing the sand away from the front of the feeders and runners immediately after solidification.

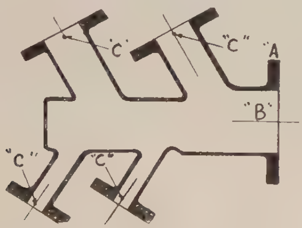

FIG. 13.—FOUR-WAY PIECE.

The explanation given seems fairly clear, but to simplify it Fig. 14 has been prepared, which shows a moulding box with the feeders marked "B," "B1," "C" and "C1." The runners are marked "D" and "D1." The contraction is in the direction of arrows marked "A," therefore the sand in front of the feeders marked "E" should be slackened away with the use of a thin steel bar, thereby preventing contraction being retarded at these points.

The contraction of castings in all metals, including steel, cast iron, and non-ferrous alloys of any type, requires to be carefully attended to, as will be seen in the diagram in Fig. 15. This figure shows that contraction movements can be the cause of considerable trouble. It is of great importance, where silicon bronzes are concerned, to ensure that contraction is not retarded, as it operates more rapidly than is the case with other brasses or bronzes.

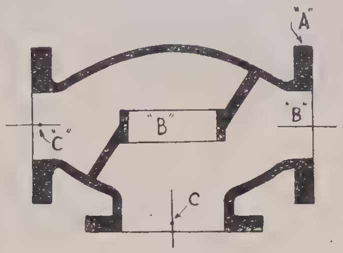

FIG. 12.—STOP-VALVE CASTING.

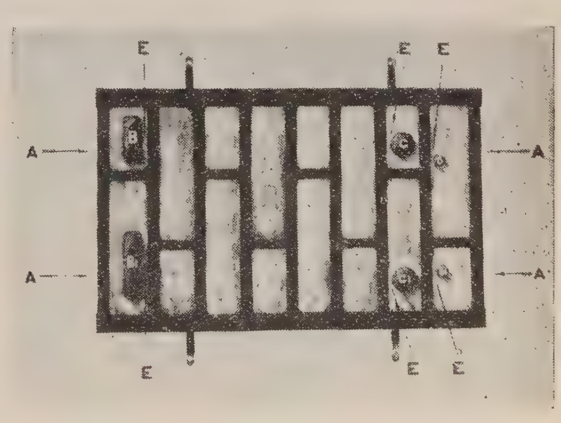

FIG. 14.—MOULDING BOX WITH POSITION OF RUNNERS AND FEEDERS.

A good idea to adopt in the case of long castings made in dry sand is to make the mould and cores on flimsy lines in front of flanges, as shown in Fig. 16. The cavity shown in front of the flanges in the mould does help considerably in the case of dry-sand moulds, for castings of 3 ft. or over in length. Components up to 25 ft. in length have been cast in silicon bronze, and before the practice detailed was used, trouble was experienced with contraction cracks, which disappeared after the precautions indicated had been carried out, and good castings were afterwards obtained.

The word shrinkage is sometimes used for contraction, and this word can cause confusion in technical circles, because liquid shrinkage occurs in a feeder or riser. However, the subject referred to here is the contraction which takes place just after the pasty stage down to a cold casting. Where moulds are made by either the green-sand or skin-dried methods, there is no need to take any extra precautions to combat contraction. Experience has shown that a perfect casting, if there be such a thing, can be made by such methods without any contraction troubles.

Short Freezing Range Undesirable

The metal has been referred to as having a short freezing range, by those who have been laboratory trained, and possess no foundry practice or experience. These individuals have often stated that, due to this, the metal is a good casting alloy—a very widely held theory. In the author's opinion, it is untenable, unless other conditions, such as the inevitable contraction, are correct. All metals with short freezing ranges, *i.e.*, those which set very quickly, are more difficult to handle in practice so far as contraction problems are concerned, than are those with longer freezing ranges. This is due, in the author's opinion, entirely to the metal not being sufficiently long in contact with the surface of the mould and cores to soften them before the pasty stage of the metal has been reached, after which stage contraction commences to occur.

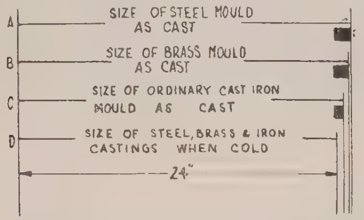
A
SIZE OF STEEL MOULD AS CAST
B
SIZE OF BRASS MOULD AS CAST
C
SIZE OF ORDINARY CAST IRON MOULD AS CAST
D
SIZE OF STEEL, BRASS & IRON CASTINGS WHEN COLD
24"

FIG. 15.—COMPARATIVE CONTRACTION OF CAST METALS.

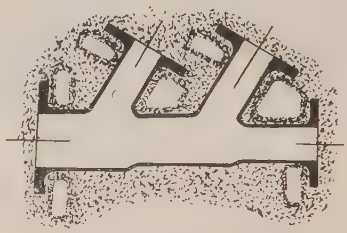

FIG. 16.—METHOD FOR LONG DRY-SAND CASTINGS.

It will be appreciated, therefore, that this is the main reason why the point of making the cores as flimsy as possible has been stressed. They assist in their heating up, and so help the contraction to take place without hindrance. It should not be thought that P.M.G. metal or silicon bronze is the only alloy that should be controlled for contraction, as the same feature is very important in the case of gunmetal. Many jobs have been rejected through defects caused by holding the contraction due to strongly-made cores with thick walls of sand instead of thin ones.

A study of high-phosphoric iron, which is liquid in the mould longer than many other metals, reveals, in the case of rain-water pipes, that these castings cannot be considered as simple where this important question of contraction applies. However, trouble is never encountered, as the cores are heated up by the metal having a long freezing range, and therefore the contraction is taking place on a soft centre or core due to the time lag before freezing commences. If the reverse order existed in this instance and the iron had a short freezing range, there would probably be much more trouble from contraction with these pipes than exists today.

There are many opinions regarding this question of freezing ranges of materials which are melted to cast, and it is a very important subject. In the author's opinion, it does not follow, as has been suggested by many, that metals with short freezing ranges are the best for making good castings, unless the practical foundryman makes his contribution as explained.

Scrap Remelting Data

The warning is again repeated that separation of P.M.G. scrap is of the utmost importance, and on no account must it be mixed with other non-ferrous metals. The necessity of keeping P.M.G. metal scrap separate must be rigidly adhered to. P.M.G. metal scrap is of a reddish colour, and can therefore be easily selected and separated from other scrap in the dressing shop. If great care be taken in this respect and the metal is kept entirely separate from other brass, it can be remelted repeatedly with very small melting losses, and with no detriment to its casting or mechanical properties. It is, of course, necessary to see that melting temperatures are kept within the range detailed earlier. As an example of this, the following figures (Table I) show the losses of each of six melts, starting with 150 lbs. of metal.

The average loss per melt of the above works out at 0.66 per cent., the gross weight of the metal cast on the first melt was 150 lbs., and the gross weight of the metal remaining at the end of the sixth cast was 144 lbs. The tests which were carried out from these six melts gave the results set out in Table II.

It is noteworthy that at the conclusion of the sixth melt the analysis was practically identical with that of the initial melt, the ingredient loss being negligible. The first column in the above table indicates the temperatures at which P.M.G. metal may be cast without any fear of deterioration or lessening of the mechanical properties. Thus, scrap may be repeatedly melted, the loss being negligible.

The information on test results so far given is but a very brief account, and many other tests have been carried out, the details of which can be made available if there be a real demand. It is of interest to note that P.M.G. metal has been used extensively in the past, and no less than 40,000 castings have been made in the completion of five ships. The "Strathnaver," for instance, had 7,562 miscellaneous castings incorporated in its make-up, whilst one gunboat had no gunmetal aboard.

In conclusion, the author expresses thanks to Sir James Callander and Sir Robert Beeman for permission to use the photographs and other information connected with the subject.

TABLE I.—*Melting Losses of P.M.G. Metal as Revealed by Repeated Remelting.*

No.		Weight	Loss
No. 1	Original weight	150 lbs.	
	Weight of test bars	14¼ „	
	Weight of ingots left	133 „	
		147¼ „	
	Loss	2¾ „	=1.83 per cent.
No. 2	Weight of ingots melted	133 lbs.	
	Weight of test bars	29¼ „	
	Weight of ingots cast	102 „	
		131¼ „	
	Loss	1¾ „	=1.32 per cent.
No. 3	Weight of ingots melted	102 lbs.	
	Weight of test bars	14¼ „	
	Weight of ingots cast	87 „	
		101¼ „	
	Loss	¾ „	=0.74 per cent.
No. 4	Weight of ingots melted	87 lbs.	
	Weight of test bars	12¼ „	
	Weight of ingots cast	74 „	
		86¼ „	
	Loss	¾ „	=0.86 per cent.
No. 5	Weight of ingots melted	74 lbs.	
	Weight of test bars	14 „	
	Weight of ingots cast	60 „	
	Loss	Nil.	=Nil per cent.
No. 6	Weight of ingots melted	60 lbs.	
	Weight of test bars	40 „	
	Weight of ingots cast	20 „	
	Loss	Nil.	=Nil per cent.

DISCUSSION

MR. W. BROWN said that he could also claim, in a small way, to be an early experimenter in the use of silicon bronzes. In July, 1930, the foundry with which he was then associated did much work in regard to them. One job was an eight-way steam valve with, he thought, a pressure of about 2,000 lbs. of steam. They had always made this particular valve in Admiralty gunmetal. On this particular occasion the firm were informed that the metal would be supplied to them in the form of P.M.G. metal. When the ingots were received, he did not altogether like the look of them from a foundryman's point of view, so he inquired what was the best practice. The reply was that the usual practice with regard to Admiralty gunmetal would more than suffice. They proceeded to make the valve, which was about 8½ cwts., if he remembered rightly, using the same procedure as with Admiralty gunmetal. He was afraid Mr. Machin would have been very disappointed with the result; it was a complete failure. In the case of a second one, they adopted their own methods and followed, more or less, the manganese-bronze practice. The casting was made successfully, and, as far as he was aware, it was in operation at the present time.

MR. MACHIN said that it would be incorrect to state that the casting and feeding arrangements for silicon bronze were the same as for gunmetal. There must be ample feeding arrangements provided, mainly on account of the short freezing range. It shrank away peculiarly and was not like gunmetal in this respect, and it had not a dendritic appearance on the top of feeders like gunmetal. The alloy contained all high-melting elements which cooled very quickly towards the solidification point. If the metal was properly fed and properly run, there should not be any trouble with it at all, or no more than is the case with gunmetal. Trouble had been experienced with it, but in the light of the experience which was now available, it could be cast quite as well, or in many cases better than gunmetal.

TABLE II.—*Tensile Properties of Remelted Metal.*

Casting Temp., deg. C.	Melt No.	M.S. Tons per sq. in.	Y.P. Tons per sq. in.	E. per cent. on 2 in.
1,140	1	19.2	11.6	10
	1	18.8	10.4	9
1,180	2	20.0	12.4	9
	2	20.8	12.0	11
1,140	2	20.0	11.6	10
	2	20.0	11.6	10
1,140	3	20.0	11.2	10
	3	20.4	11.6	9
1,140	4	20.4	12.0	9
	4	22.0	11.6	13
1,140	5	19.6	11.6	10
	5	19.2	11.6	10
1,160	6	21.2	11.6	13
	6	21.2	10.8	13
1,140	6	21.6	12.4	11
	6	20.8	11.6	10
1,130	6	20.8	11.2	12
	6	22.0	11.6	13
	6	21.2	11.2	12
	6	20.0	12.0	11

Running Methods

MR. A. HOPWOOD referred to the running power or the distance to which the metal would travel. In the case of an 8-ft. casting of five-sixteenths metal, containing, say, 1½-in. flanges, which was quite a usual thing in shipping circles, did Mr. Machin prefer to use the method of sprays or to use a large number of down-runners through the top part? Coupled with this point, of course, came the question whether the metal would top run quite successfully. From what experience he had had, he thought it would, namely, that the metal could be dropped straight into the mould in a similar manner to the dropping of gunmetal. He assumed that the tail shaft liners referred to in the Paper were run flat, with the usual method of runners along the joint. He did not quite understand the failure of the tail shaft liners and the *lignum vitæ* supports for the shaft, and would be pleased to receive a little information upon the point.

MR. MACHIN assumed that Mr. Hopwood meant, when he referred to the running distance, the distance from the flange.

MR. HOPWOOD said he meant the distance the metal would run and keep lively.

MR. MACHIN replied that it could be run up to any length, to 30 ft. if necessary, without any trouble. The liners mentioned were cast vertically, not horizontally. He never cast tail shaft liners in silicon bronze horizontally, but always vertically, while in gunmetal they were cast horizontally. With silicon bronze, the runners were spaced round the top, just as a liner would be cast in iron. The runners were spaced three or four inches apart all round the top. The metal was put into a basin and released very quickly, and the quicker it was cast the better.

The metal would travel any length within reason, as it was very fluid whilst hot; the castings came out very sharp from the mould, and there was no trouble in that respect. Nor was there any trouble in running if the correct temperature was maintained, and there was a wide range of temperature available, *i.e.*, 1,000 up to 1,150 deg. C.

Regarding top runners direct on to the casting, he did not use them; he did not say it was not right to do so, but he usually ran straight into the flange to keep all the metal together or in a pool when filling the mould. When there were seven or eight sprays on a valve, it was not possible to plug the runners, as in the case of a one-plug runner. It was usually arranged to run through the flange, and little trouble was experienced.

Tail Shaft Liner Bearings

Turning to the question concerning wear on *lignum vitæ* strips, looking at the structure of the metal, at 200 magnifications, it would be found that there were a considerable number of spots in the matrix, which could be seen very clearly; these, in the author's opinion, were a silicon-iron alloy which may be slightly abrasive. It had been argued by several metallurgists that the alloy would run satisfactorily on white metal bearings. Personally, he did not know whether it would or not; he thought that probably it would, but definitely it would not run on *lignum vitæ*. There was something abrasive about the alloy, so that, after a certain amount of running, there was a scoring of the *lignum vitæ,* and instead of the ship coming back from a voyage with a round bush, it was found to be slightly oval. In view of this, the application of silicon bronze for a tail shaft liner was discarded in favour of gunmetal.

No fault could be found with the castings in regard to quality or on pressure tests, or when they were being machined. Again, the rubbing away of the *lignum vitæ* strips, may probably have been due to there being a little free silicate existing somewhere in the casting. This failure was experienced in, he thought, three or four ships, although liners in silicon bronze were fitted in many more ships. Of course, it was a big job to take out tail shaft liners and put in new ones. The rubbing away took place in the case of ships doing 20 knots or over travelling to and from Australia, and, in his opinion, this was a very severe test for silicon bronze on *lignum vitæ* strips. On slower-running ships it may have proved to be satisfactory. Gunmetal no doubt is ideal for this application, but silicon bronze, due to the scoring action, proved unsatisfactory. Why wood was used in the bushes he did not know, as all the Admiralty ships were fitted with white metal. It was sufficient for the Admiralty to know the application was not good with wood; therefore, they naturally would not risk running them on white metal, and, in the author's opinion, it was a correct decision to make.

MR. W. N. COOK, B.Sc., asked if castings had been made in open sand, to which Mr. Machin replied in the affirmative.

Making the Hardener

MR. MACHIN, continuing, said some members had inquired the best way to get the tin substitute or hardener. If it had to be used throughout the country, the best way in his opinion was to go to someone dealing with the melting of alloys, as the hardener must be manufactured on sound metallurgical lines. If the iron, silicon, copper and the manganese were not properly alloyed, trouble would ensue in the final alloy. There was no time in the present emergency for experiments in the preparation of the hardener by any foundry.

Leaded Silicon Bronzes

MR. A. PHILLIPS said that apparently one of the chief difficulties with regard to silicon bronze was the formation of silicates. A similar trouble was experienced in regard to aluminium silicon alloys. In the manufacture of the hardener did Mr. Machin reduce the stirring? For instance, speaking offhand, if lead was present then lead silicate would soon form, and by stirring it greater trouble would be caused eventually, because it would be stirred into the metal. Owing to the specific gravity of the silicate it would remain suspended in the metal. Therefore there would be hard spots in the castings when they came to be machined. This was, of course, merely theorising. When manufacturing the hardener, did Mr. Machin stir the metal as little as possible or did he stir it much; also did he find he had to stir it under a flux? What method did he use to avoid making a silicate, because that appeared to be one of the chief difficulties in the making of the alloy.

MR. MACHIN said the hardener had the most silicon in the melt. Mr. Phillips had brought forward a particularly important point: silicates would form if the melting was not properly looked after. As shown on the screen there should be half the silicon in the bottom of the crucible and all the copper on the top. The copper commenced to melt before the silicon started, so the silicon was therefore covered just on the pasty stage with copper, only little stirring was done, a start was made to melt the hardener as shown with a 300-lb. pot, the charge was put in and the pot was kept covered all through the melt. At a given time the lid was taken off, the phosphor copper added, then it was lightly stirred. The melt was then allowed to remain another 10 mins., and then taken out and cast into ingots. There was 100 lbs. of hardener melted in a 300-lb. pot, this method eliminated a lot of stirring. When the lid was put on the crucible it was not touched for about 1¾ hrs.; it took roughly 2 hrs. to melt. If the crucible were left uncovered during the melting of the various elements in the hardener, the silicates mentioned by Mr. Phillips would appear because more stirring would be necessary due to the melt being delayed which caused some of the constituents to stick to the pot side.

Lead Addition to Alloy

Lead had been added to the alloy quite successfully, up to 10 per cent., but it was a tricky job. Only a little stirring was done and the casting operation was carried out very quickly, to prevent segregation in order to get a good structure. He regretted that he had not brought some fractures of the metal with him containing lead, but they could be forwarded if the members desired to use or see them. They were very interesting to see.

A number of bearings were made for a wire mill in 8 per cent. lead silicon bronze, the scrap was returned and it was expected that it would be paid for on the same ratio as phosphor bronze. Upon using it again it was found that the pressure under which the bearings had been operating in the mill had caused a certain amount of small cracking to occur. Oil had percolated into the cracks, and was the cause of a considerable amount of trouble occurring in regard to the melting of the scrap. With 3 per cent. of lead in the case of many bearings the alloy had worked successfully and there was a perfect structure in the fractures. Microstructures had shown the lead to be perfectly alloyed.

Scrap Segregation

MR. F. DUNLEAVY said that it was generally admitted that silicon bronze was not suitable for bearings, but he would rather deal with a more important point, namely, the contamination of many bronzes by silicon bronze scrap, or the contamination of ordinary gunmetals by silicon bronze and the contamination of silicon bronze by the tin in phosphor bronze. He would like to hear an expression of Mr. Machin's views upon the point. How could he separate the two scraps not only from the fettler's shop, but also from the machine shop? Also, would Mr. Machin give some information regarding the rotary furnace atmospheres and silicon bronze. Was there the same action as would be obtained through the crucible? Contamination of a furnace atmosphere was an important matter, particularly from machine shop scrap.

MR. MACHIN repeated his statement that the best plan to avoid contamination was to keep the contaminating substance out. Some people said that small percentages of tin would not do any harm to mechanical properties. This was correct up to a point. The mechanical properties were equal to the required Admiralty specifications, but it was detrimental to the casting especially for pressure applications.

Dealing with the segregation of scrap, it could be definitely separated in the foundry. Colour was a sufficient indication. Silicon bronze or P.M.G. metal showed red in the machine shop, therefore the silicon bronze could be picked out quite easily from gunmetal borings. No concern need be felt regarding furnace atmosphere provided the metal was kept covered, charcoal being satisfactory. It could be melted in a rotary furnace, but he did not think that furnace was a good type to melt silicon bronze. If the metal was not kept covered it would pick up oxygen very readily at high temperatures.

Die Casting

By H. J. MAYBREY, B.A., D.I.C.*

Die casting is a term covering a very wide field of foundry technique. In its most general aspect it can be defined by saying that die casting is the action of introducing molten metal into moulds of such a type that they can easily be assembled and taken to pieces, these moulds remaining relatively unaffected by the action of the molten metal poured into them so that they can be used relatively indefinitely for the production of castings. Please note that the word "relatively" has purposely been used twice in this description. It is important to mark this "relativity."

It will be noted that in its widest aspect die casting strictly speaking covers the production of rolling slabs, extrusion billets, wire-drawing billets, etc. However, for the purpose of this talk and discussion it is proposed to cut out certain processes which might be termed in the literal sense, die casting. Included in this cut-out is the production of solid blocks of metal which are made in order that rolling, extruding, forging and wire-drawing operations may subsequently take place. This admittedly excludes without any great logic certain specialised methods of production in metal moulds, such as "flush" casting, the Cothias process, centrifugal casting and others which have a limited, though quite useful, scope. This has been done not because the processes mentioned are not of much use, but because it would not be possible to deal with all the various methods of producing castings in what one might term "permanent moulds" in a short talk.

Two Methods of Die Casting

In practice, when reference is made to a die foundry, one usually means a foundry which is producing castings by two methods or by one of those two methods. These two methods are usually termed in this country:—(1) Pressure die casting; and (2) gravity chill casting. The main difference between these two methods lies in the manner in which the molten metal is put into the mould.

With the pressure die-casting method the metal is forced into the mould mechanically with an applied force. With the gravity chill-casting method, the metal is poured into the mould with only the action of gravity to carry it into the recesses of the mould. In passing, it should be noted that in the United States the expression "die casting" usually means pressure die casting, and what here is termed gravity chill castings are called permanent mould castings.

This is rather unfortunate, since sometimes confusion arises. This confusion is particularly apt to come about when a customer is a branch of an American concern or has strong financial or commercial associations with the United States. The misfortune of this confusion lies in as much as castings made in a pressure die-casting machine can usually be relied upon to be cast to much closer limits than those made in gravity chill moulds, and the customer may be counting upon cutting out a considerable amount of machining which he is unable to do if he receives gravity chill castings.

Now the author would venture to state that die casting (using the term in its widest sense) came into being and developed into the very large industry it is to-day, mainly as a result of economic, production-rate considerations. There are, of course, many other advantages die castings can give, but these advantages were usually looked upon as pleasantly incidental ones, though nowadays it is quite frequently these incidental advantages that have taken the first place in deciding whether a casting shall be made in a metal mould or in a sand mould.

The Field for Die Castings

Turning away abruptly from this preamble, and proceeding to consider the subject of die casting itself, a few rhetorical questions suggest themselves:—

(*a*) *What metals (or alloys of metals) are usually die cast?* They are in groups:—

(1) The low melting point white metals, with tin or zinc base.
(2) Brasses.
(3) Aluminium bronzes (being rather specialised forms of yellow metal).
(4) Aluminium alloys.
(5) Magnesium alloys.

Die castings in all these five groups are quite commonly encountered.

(*b*) *What other metals could be die cast commercially?* Well, quite apart from the production of cast-iron pipes up to quite considerable dimensions by the centrifugal process, a quantity of work has been done in perfecting means of producing iron castings by pressure methods in permanent metallic moulds. There is somewhere in the author's possession at this moment a very interesting pressure die-cast piston pot in special iron, which was made for the production of piston rings. It is not sought to go into the controversial matter of the ideal method of producing piston-ring castings, but it does seem likely that this method of production, *i.e.*, a pressure die casting of "cast iron" is worth a good deal of consideration. The practical study of the problem of rapid production of cast-iron piston rings by mechanical means may open up eventually a vast industry, in a somewhat similar manner to that in which the invention and development of the "Linotype" printing machine, led ultimately to an established prosperous and extensive white-metal die-casting trade.

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* Deceased 1942.

It would be, of course, true to say that practically all the existing commercial alloys could, by the exercise of ingenuity, be made susceptible to die-casting methods, but the demand might be so small and the ingenuity required to produce useful castings so great as to put the method outside purely economic consideration.

(*c*) *What determines whether a casting shall be made as a sand or die casting, it being assumed that it is reasonably regular practice to produce both sand and die castings from the alloy in question?*

This is a very wide question indeed. In fact, it is a question which is sometimes solved in a very unscientific, unplanned and illogical manner. It is unfortunately often left to one of the two parties immediately concerned, *i.e.*, a foundry manager or the purchasing department of the customer. It is, of course, obviously much more sensible if the matter is mutually discussed by both parties with their technical advisers in attendance, for there are other considerations involved than the purely immediate economic ones, and it is the balance of the factors which should influence the position.

Aluminium Alloy Castings

Take as an example aluminium alloy castings. These are a class of castings with which the author is more particularly concerned these days, and it is proposed to follow the example through in fair detail to endeavour to exhibit certain of the factors which come into play.

It will be assumed that the proposed casting is a fairly simple one, such as, for example, a small hand wheel of 4 or 5 in. diameter, with a raised orthodox rim and four spokes joining together in a central boss of simple cylindrical type. The number of castings contemplated to be ordered is, say, 500.

A wooden pattern for such a casting might cost a few shillings, and even if the pattern were split and duplicated by mounting on a pattern plate, the cost is not a great deal. A metal mould, or die as people term it, would possibly cost many pounds to make, as the wooden pattern costs shillings.

Admittedly, as far as cost for such castings affects the customer in the first instance, a simple arithmetic sum settles the issue—*if* such total cost for the order placed (*i.e.*, 500 castings) were the sole deciding factor. This is, of course, sometimes the case, and in the instance just quoted, it is very probable that a sand cast article would prove cheaper than the die cast one. For, although, probably the rate of production of a die casting would be somewhat more rapid, hence the castings—as castings—likely to be a little cheaper, the difference for 500 castings would probably not be anything like enough to off-set the considerable difference between the cost of a wooden pattern and the cost of a metallic die.

Analysis of Production

By introducing the relevant factors one by one it can be shown how they could affect the arrival at a sound and logical decision.

(1) *If the order for 500 castings is merely a preliminary one.* The customer is really putting out a feeler to market some new departure. He foresees the possibility that he will in fact within a short time be ordering such castings at the rate of 500 a month, and this for some long time. After a few repeat orders of this type he rapidly neutralises the difference in preliminary outlay for pattern and die. Hence, he rapidly gains an advantage by specifying die castings, but this is a matter in which his judgment of future possibility can be the sole guide.

(2) *The casting is one which requires, in order to be employed in his engine or instrument, to be machined all over.* Now, by the very nature of the comparative exactitude of the die casting method, it is possible that the amount of machining required on the die casting may be substantially less than that required on a sand casting. In consequence, there are lowered machine-shop costs with the die casting, and the actual saving of costs may make the purchase of even such a small quantity as 500 die castings the cheaper ultimate proposition.

(3) *The wheel is a highly stressed part requiring heat-treatment.* Now, a metallurgical factor comes into play as, generally speaking, especially with aluminium alloys, the effect of casting into a metal mould with consequent rapid freezing is to produce a much finer grain-structure in the alloy than could be obtained with a sand casting. The die casting, moreover, is less likely to suffer from minor porosity troubles. Hence, the die casting, particularly after heat-treatment, is likely to be stronger and more ductile and more resistant to shock than the sand casting. This fact may be of such importance as to be practically paramount, and would decide the issue.

(4) *The designer of the article may not be quite certain that his ideas are final.* Experience in use may show that considerable modification in design is required. Now, with a wooden pattern quite large modifications or additions can usually be made at small cost, but frequently such modifications or additions would involve a large outlay with an existing metal die. It does quite frequently occur that a complete scrapping of an original pattern is required, but this is not the calamity financially that it would be in the case of a die.

(5) *The production of the castings is a matter of profound urgency.* With this problem it must be borne in mind that it is very much quicker to produce wooden patterns and core-boxes (or even to prepare and clean up metal pattern plates) than it is to produce satisfactory casting tools.

It is not pretended that the foregoing list of factors is by any means exhaustive. They are merely cited as typical factors, to illustrate the contention that the problem of determining whether or not die castings or sand castings are most suitable should depend upon frank co-operation between the foundry and customer.

Function of a Toolroom

(6) *What is the function of a toolroom in a die foundry?* The toolroom occupies a vastly different relationship *vis-à-vis* the foundry than does the pattern shop to the foundry. For it is in the toolroom that, in the deepest sense, the casting is made. Included in the toolroom there is of necessity the tool designer's office. The author has always maintained, as his own die department manager will confirm, that die casters should be only people who pour molten metal into a hole, but here must be added a very strong proviso to this rather sweeping remark, for it is in this case essential that the die should be correctly designed, machining of the die blocks and cores accurately carried out according to the design. In such a case the production of castings from that die should be, subject to efficient supervision by the foremen and chargehands.

It is reasonably certain that if anyone suggested that the production in the sand foundry of a satisfactory casting from a really well-made pattern was an automatic affair capable of being undertaken by a mildly intelligent man or woman after a few days' training—he would antagonise, and rightly so, all the skilled moulders in the United Kingdom.

In making this contention of the all importance of the toolroom, it is not for one moment suggested that it is possible to see a customer's blue print, then to sit down for a few hours making sketches, to work these sketches up into production drawings, to use these production drawings in machining up lumps of cast iron and steel, to assemble the machined lumps into a composite die, and to pass it out to the foundry with every certainty that satisfactory castings will automatically pour forth as soon as the die has been warmed up. It is certainly not as simple as that—although such cases do occasionally occur. It is most frequently the case that the die as first produced has to undergo fair modification (even assuming dimensional accuracy) before sound and satisfactory castings can be easily obtained.

Every Die Casting a New Problem

In other words there is no really satisfactory textbook on die design by the use of which automatic success can be obtained if certain rules are followed.

General experience can be gained as time goes on, but every new proposed casting is in effect a new problem. Cast iron and steel are rigid materials, impervious and solid. Hence gating, venting, angles of pour, etc., are very important questions to consider when laying out the outlines for the design of a casting tool.

It is now proposed to end this short talk, realising quite well that only a few very general remarks have been made. Foundrymen will appreciate that the course of a dozen lectures, each at least an hour long, would be really inadequate to cover effectively the subject of die castings. The remarks have been made merely to stimulate and start a discussion. The author is only too glad to enter into such a discussion, but asks speakers to bear in mind that by training and practice he is a metallurgist turned into a commercial manufacturer of castings. He is *not* a tool designer, though, quite naturally after many years of close association with the production of gravity chill castings in non-ferrous metals, he does occasionally have ideas about the best method of constructing a particular die.

[The lecturer then displayed several examples of gravity chill castings and a simple example of a die from which successful castings can be produced.]

DISCUSSION

[Before the discussion was opened, the author briefly reviewed the sample castings which were exhibited.]

MR. MAYBREY said that all the exhibits were gravity chill die castings. There was, amongst them, a particularly spectacular looking casting, but, as was often the case, this one was not so difficult to make as a casting as some others which appeared to be more simple. The design of the die for this casting, however, had certainly given a headache to those who had to make it. This casting, in fact, illustrated a point he had tried to make in his talk. In other words, the original design of casting had proved eventually to be of no great use.

It was a costly die, and under the "part contribution to tool cost" scheme it had cost the customer about £500, and his own die-department considered they were at least £200 out on the deal. He had warned the customer that it would have been infinitely more sensible to have made a pattern and series of core-boxes in the first place, which might have cost about £50, so that a series of modifications could have been made to the pattern at relatively little cost, and before a final decision was come to. It was an aggravating thing that only six castings were made off this particular die, when the decision was made by the designer of the article that such modifications would have to be made, and that the die was useless.

This particular casting was made in the L.33 material in those good old days, when one just went out and bought it, and there was no necessity to ask anyone's permission to purchase! For a complicated casting, such as the one he had just referred to, L.33 was, of course, an ideal metal, being reasonably close to eutectic composition.

Brass Inserts

Referring to another, and smaller, casting, Mr. Maybrey said he brought it along to illustrate a point regarding inserts. Having brass inserts in castings was not very sound practice in general. It would be noticed that there were seven inserts in this particular casting, and he would go so far as to say that the customer would probably have had nine, if he had had his way!

The fact was, that the introduction of such inserts caused strains and stresses, and blowhole troubles of various kinds, and it was seldom a practical proposition. It was, however, very difficult to make customers see these points, for a customer seemed to think that, in having inserts cast in, he was gaining in having to do less final machining. Often, in fact, a customer had to pay considerably more for the finished castings, and the ultimate cost was more than if he had gone about the job in a straightforward manner.

Dealing with another of the exhibits, Mr. Maybrey said it was made to the Air Ministry Specification, DTD.424, which was made up as an aluminium-copper-silicon alloy, having very useful, all-round properties. Turning away from the question of the exhibits, Mr. Maybrey said that he had purposely avoided dealing with the purely technical side of die casting, because he realised that the subject was too vast for one lecture, and, had he gone on, there would probably have been very few people left in the room by the time he had finished.

Runners and Risers

He then exhibited a die which he had brought along with him, to show the general principles of the construction of a casting tool, at the same time drawing attention to the small casting made with this die. This casting exhibited a fact he had referred to before, and that was, that with small die castings, the ratio of the weights of the runner and riser of the finished casting was often quite considerable; generally a much larger ratio than would be the case in a sand foundry. In this particular case, the ratio of these weights was something like 10 to 1, and he was of the opinion that sand founders would not be very pleased with the prospect of making castings with the weights of this ratio.

No Equilibrium Diagrams!

MR. J. F. KAYSER said he was not impressed by the castings which Mr. Maybrey had exhibited, although they looked very spectacular. Did not Mr. Maybrey think that every die-caster should have an X-ray apparatus and examine every new casting to make sure it was satisfactory.

MR. MAYBREY: Yes.

MR. KAYSER said that until the caster obtained a succession of castings that were sound every one should be examined and not only 10 per cent. It might seem difficult to do this from the commercial point of view so far as the X-ray apparatus was concerned, but there were hundreds of foundries who should examine all their castings in the way he had mentioned, and if they all decided to do it—he did not mean under the present difficult circumstances—the cost of X-ray apparatus would drop to a fraction of what it was at present.

Another question was why castings such as they had been shown that evening could not be produced with less than 50 per cent. of scrap. He was not speaking of the runners and risers, but of scrap castings. Finally, Mr. Kayser said he had listened to a large number of lectures in which aluminium alloys had been mentioned, and he was glad that on this occasion no reference had been made to equilibrium diagrams. Most metallurgists who dealt with aluminium seemed very much like the child who had got to about the 12-times table. In other words, they had got to the thermal equilibrium diagrams and, he feared, would never get any farther. Therefore, he was thankful the lecturer that evening had not mentioned them.

The Pre-War Market

MR. V. C. FAULKNER said he could not help wondering what Mr. Kayser was thinking about in suggesting that die casters should invariably use X-ray apparatus. In peacetime, at all events, die-casting was largely confined to the manufacture of things like carpet sweeper parts and ash trays. A large percentage of output was novelty and domestic engineering articles.

MR. KAYSER replied that in peacetime he was concerned with the making of 50,000 die castings a day, and they were all X-rayed. It was necessary to do this because it was not certain that they were sound. The castings in this case were razor caps. Incidentally, he asked Mr. Maybrey what he could do in the way of die-casting a small piece which he handed to him.

Need for X-ray Examination

MR. MAYBREY said he was heartily in agreement with Mr. Kayser, when he said that to X-ray die castings was sound practice; in fact, it was often done. In certain classes of castings which he had to make, every one was X-rayed; not sometimes only one in ten. If he had his way, he would put down large X-ray apparatus in his firm to-morrow, provided he know where to put it, but unfortunately he had no room. There were, however, excellent facilities for having castings X-rayed, and it was quite a regular practice, certainly in foundries making big and difficult die castings, to X-ray them. At the same time, there were limits as to the extent to which this practice could be carried. Just before the war, he was making some Diesel engine piston castings, which unlike the usual Diesel piston castings, were made completely as gravity chill die castings, *i.e.,* with steel cores, and he claimed that as far as his knowledge went, at that time, these were the largest single gravity chill die castings made in this country, weighing each just over 4 cwt. The material used for making these castings was an aluminium alloy containing 18 per cent. of silicon and 3 per cent. of copper, which had a very wide melting range, and in consequence all the difficulties that accompanied a prolonged freezing range.

If it had been possible easily to obtain X-ray examination of these castings, it would have been a tremendous advantage, as it had taken him quite a long time and laborious and detailed examination of each casting before he was able to produce a basically sound one. He maintained that the high degree of excellence of castings which war conditions imposed had given a very great impetus to this question of X-ray examination. It would, undoubtedly, affect the practice after the war, and might so reduce the price of small X-ray apparatus that such type of examination would be quite common in all foundries worth calling foundries. With regard to what Mr. Kayser had said about the equilibrium diagram, it should be remembered that metallurgists must have some basis on which to formulate their ideas. Thermal equilibrium diagrams were the basis of most metallurgical ideas. All professions had their own particular jargon which he admitted, at times, became somewhat boring to other people.

He could definitely not agree with Mr. Faulkner's somewhat sweeping remark that die castings prior to this war were almost largely concerned with such things as ash trays. The casting which Mr. Kayser had handed to him was certainly awkward. It was a very solid lump of metal, attached to a thin base, but although he felt he should not advertise his own firm, he believed he could produce a satisfactory die casting, even in this case. It must be remembered that die casting was, by definition, a casting process, and it was unfair to make comparison where the metal was being worked, as for example, in forged products.

Competition with Sand Castings

MR. G. C. PIERCE said that quite frankly he did not know anything at all about die casting, and he did not particularly want to as he had enough to put up with in what he was doing otherwise! At the same time, one could not help admiring the die castings that had been exhibited by Mr. Maybrey, knowing a little about the cost of tool making, patterns and moulds. It was interesting to hear the figure mentioned by Mr. Maybrey of the cost of the tool for the complicated casting that had been examined, and personally he would have expected the cost to be even more.

Sometimes he had wondered how die castings could even compete with sand castings in the case of the small castings which they had seen. The rate of production of small sand castings was very high indeed, and it seemed almost incredible that these small die castings could compete with sand castings.

Some Factors of Importance

MR. MAYBREY, on this latter point, said there were many savings made in die casting as compared with sand casting, considering everything including re-melting, etc. At the same time, there were cases in which a sand casting would prove quicker and cheaper to make. He held no vested interest in die casting and in appropriate cases he would not advise a customer to have die castings; he would strongly advise sand castings, for economy sake. There were, however, incidental advantages which sometimes went with die casting. For instance, with sand castings a certain amount of machining might be required to make useful articles. Again, there was a certain amount of prejudice on the part of some people against die casting. They had been in the habit of using sand casting and could not get out of that habit. On the other hand, he had a certain number of customers whom he called American by origin, in that they had been brought up very largely in an atmosphere of die casting and they automatically asked for die castings. If a relatively small number of articles was required, it might be better to have sand castings, and personally he held no brief one way or the other.

Accuracy of Die Castings

MR. KAYSER said he thought it was a mistake to think that die castings gave absolute accuracy. His experience did not suggest that die castings were particularly accurate, and he regarded the question of grain and physical properties as the important thing.

MR. MAYBREY replied that "accuracy" was a relative term. A gravity chilled die casting could be guaranteed to be accurate to within 0.005 in., which was not a bad figure. Naturally, after about 30,000 articles had been taken from one die, the die would begin to feel a bit tired, and steps would have to be taken to restore the accuracy. With aluminium alloys, a die did not last indefinitely. During a long run-off, there would have to be repairs to the die, and it might be eventually that there was very little of the original die left. It might even be necessary to make new dies altogether. Curiously enough, it was very difficult to get statistics of die life. He had been trying to get such figures for many years in connection with aluminium alloys, but there seemed to be no hard-and-fast rule as to the length of time a die would last. In the case of aluminium bronze, this had a very corrosive effect on dies, and it was necessary continually to replace them.

In going into the economics of die casting it was necessary to bear in mind the question of die replacement. The usual practice was that the customer paid what was humorously called "part contribution to tool costs." This was a sum of money which roughly represented the out-of-pocket expenses of the manufacturer in making the tool. The manufacturer had to find the balance of the prime costs and finance his overheads. Therefore, he did not ruin a tool for the fun of doing so. The replacement of dies for a run of castings must be budgeted for in costing. With sand castings, as members no doubt knew, the customer paid right out for the pattern, which became thereby the property of the customer. The foundry held them in trust, so to speak, for the purpose of producing castings. In the die foundry industry, the tool remained the property of the foundry, although the customer had paid part of the cost. It had always seemed an interesting point to him to what would happen in the case of the voluntary liquidation of the foundry, *i.e.*, to whom did the tool really belong?

Heavy Discard

MR. R. B. TEMPLETON (Branch-President), commenting on the small casting in which the ratio of the runner and riser to the finished article was 10 to 1, suggested that it ought to be possible to eliminate a great deal of that extra metal.

MR. MAYBREY explained the precise process by means of the die used for this casting, and said that every effort was made to keep the weight of the runner and riser down to the smallest possible limits, for three reasons. In the first place, it was not desired to buy more metal than could possibly be helped; secondly, the machining involved time and money; and, thirdly, it was not desired to have more remelting than necessary. It had been found by trial and error and previous experience how to obtain the best results. He was willing to admit that, in playing for safety, he had sometimes over-played, but he would rather over-play than under-play. The extra metal, however, was perfectly good metal and had merely to be remelted.

MR. TEMPLETON remarked that in suggesting that it seemed to him possible to eliminate a great deal of the extra metal involved in the runner and riser, he was thinking of what appeared to him to be a difficulty in maintaining the initial temperature.

The Use of DTD.424

MR. MAYBREY replied that the enormous block of iron in the tool tended to maintain the temperature. The melting point of the metal used, *i.e.,* L.33, was about 600 deg. C. The temperature of the die was somewhat lower. The metal in the riser was cooler than the metal in the runner, which obviously must be so, otherwise the second law of thermodynamics would be upset.

He would state, and he believed that any tool designer would agree with him, that tool designing was not an exact science. It certainly was not possible to write a text book on tool design, except in a very general way, for a great deal depended on previous experience, although that was sometimes misleading. When misleading previous experience had led to disaster, then everything had to be scrapped and a fresh start made. For the most part, it was essential to have considerable experience with any particular alloy or range of alloys. This was well illustrated by the point of the metal termed "DTD.424." In pre-war days, when Mr. Faulkner said that the die-casting industry was only dealing with ash trays, he had a customer who purchased castings to make articles useful about the house, viz.: an electric fire. A material was required for these castings which would take a high polish and machine quite easily. L.33 was not notably easy for machining, particularly for small screw threads. Furthermore, there was a good deal of competition from Birmingham, and the cost of the raw material became of considerable importance.

He therefore decided to make up an alloy from scrap pistons to a composition which was easy to machine. Most of these pistons were made from "Y" alloy, or the Lo-Ex material or the old-fashioned L.8 alloy. A mixture of all these materials would contain aluminium alloyed with copper, silicon, a little nickel, etc. If a certain amount of silicon hardener and sheet clippings were added, a very suitable alloy was obtained economically, being mainly a ternary alloy of copper, aluminium and silicon.

Some years ago he had been impressed by some work done by two United States Navy Board metallurgists named Dix and Lyon, on the aluminium-alloy/copper/silicon series. They had come to the conclusion that an aluminium alloy containing somewhere between 3 and 8 per cent. of copper plus something between 3 and 8 per cent. of silicon—provided the total added metals altogether were not more than 11 per cent., was a very useful, general, all-round material, and this was roughly what he had obtained by melting up old pistons with the hardeners and sheet clippings. To this hotch-potch composition he had given a particular name in his own foundry. When the war came along, difficulties were introduced in obtaining the necessary raw materials to produce L.33 in vast quantities, and eventually the DTD.424 specification was drawn up, which corresponded very closely to this material he had used in making up electric-fire castings. To that extent, his firm had started off with an advantage in dealing with this material, and he had been to a good deal of trouble to write a memorandum on this subject, which he sent to the Light Alloy Castings Control. This memorandum dealt with the possible difficulties which might be found when using this metal, and he hoped and believed he had been able to help quite a few founders in that respect.

Nevertheless, many people had become so used to L.33 that they were convinced that there was nothing possible to replace it. Now, the whole point was, that these people were still continuing to use the L.33 technique when they came to designing tools to use DTD.424, and found themselves completely at sea. The interesting point, however, was that although he would not say that there were no troubles to be experienced with DTD.424 material, the difficulties originally experienced by most firms now seemed to have disappeared. This was not due to any improvement in the material, but merely because people had found the right technique of dealing with it. They might not be fully conscious of this fact, but unconsciously this was what had happened. This emphasised the remark he had made in his opening comments that nothing but experience enabled the problems to be solved.

Aluminium Bronze and Magnesium

This applied very much to the aluminium bronzes. Many years ago, when aluminium bronze was introduced, there was considerable opposition to it on the part of those who had been used to using brass and gunmetal. In fact, they could not be bothered with the new material. It was said there were difficulties in machining it, but in fact it was as easy to machine as a soft brass. Complaints in the casting technique were also made by the foundries, and there was no disposition to persevere. Slowly but surely, however, the intrinsic values of aluminium bronze had been forced upon the engineering trade, and to-day there was no difficulty in making castings from it, either die or sand, and no complaints from engineers were forthcoming.

It was almost the same story every time. When a new material or new mehtod came along, something new had to be done, and there was the unavoidable opposition. He had been early concerned with magnesium alloys, and when they were first introduced they were looked upon as almost comic materials. He had given up three or four years after the last war to developing their use, against considerable opposition, but magnesium alloys were everywhere used to-day, for the simple reason that the particular technique involved had been mastered, and was now understood.

Sand Casting Production

MR. J. C. SWAN asked Mr. Maybrey whether he would prefer to make a die casting in the vertical or the horizontal position. Remarking that Mr. Maybrey obviously had great experience with L.33, he said he himself started a firm about two years ago, knowing nothing about die casting, although he had had a long experience of sand casting. It took a great deal of time and money to get going on die castings. At first he was casting vertically and it was not very easy, although ultimately he did get a perfect casting. However, he then switched over to sand casting on a moulding machine and obtained a production rate of 20 per hour. As it was calculated that with a moulding machine with one man and a labourer it was possible to get a production equivalent to that obtained with die casting, he did not bother further about die casting. There was the point, however, that the labour cost with sand casting was greater than with die casting. It was necessary with sand casting to have a melter and also a man to close the moulds, whereas with die casting the man who looked after the casting also looked after the furnace. The fettling cost was also very much less. As a metallurgist familiar with aluminium alloys his experience had been that sand castings in these alloys, other than L.33, could not be expected to be as sound, hydraulically, as a drop forging, and that had some bearing on what Mr. Kayser had said. There was very great intercrystalline porosity in these sand castings and the only metal free from that defect was L.33. In that case the gas came out in small globules and did not lie on the crystal boundaries. If one could afford it, L.33 metal should be used.

As to X-ray examination of die castings and the criticism by Mr. Kayser that he had often found such castings not very sound, he himself had examined a large number of die castings by X-rays and found them quite good on the whole. Pressure die castings seemed to have a slight porosity underneath the skin, but using L.33 and gravity die castings, the results were perfectly sound.

Commenting on the reference that had been made to DTD.424 metal, he said he did not think this was as bad as it was painted. It had been used successfully for a large number of castings, but it was entirely unsuited to aircraft work in which there were many castings with projecting lugs. There was no ductility in 424, and it was entirely wrong to specify this material where ductility was required. The aircraft designer should indicate whether he wanted ductility, and one would not expect the designer of a locomotive or an automobile to put in material which had no ductility if ductility was required. In his view, that was the basis of the whole trouble witih 424. Incidentally, he added, if 424 were heat-treated, a great many troubles were overcome. Brittleness was reduced and the machining properties were improved. Heat-treatment did not give increased ductility, but it gave an increased impact value, which was very useful in machining.

Horizontal or Vertical Casting

MR. MAYBREY replied that he had had a fair experience with 424, and in his opening remarks he had drawn attention to one or two disadvantages. Apart from those, it had been possible to use almost any dies that had been previously designed for L.33 with very slight modification. In many cases such dies had been used with 424 without any modification at all. A point to be remembered was that, when people spoke of L.33, they were referring to metal furnished by the two best-known suppliers, both of which concerns supplied virgin metal from the electric furnace. On the other hand, 424 was a secondary metal made from duralumin scrap, etc., and the making of secondary alloys required a good deal more care. The material might be badly gassed, or there might be a large amount of alumina, all of which would have a very serious effect on the porosity and the general physical properties. Generally speaking, when dealing with secondary alloys, a great deal of care and forethought had to be shown. As to the point concerning horizontal or vertical die casting, the fact was that some castings lent themselves much better to horizontal casting, whilst others were better if cast vertically.

MR. SWAN asked how the large casting which had been exhibited had been cast.

MR. MAYBREY said he knew his foundry manager was present criticising him. Actually the casting in question was done horizontally, but his foundry manager would have preferred to do it vertically. Personally, he was not a die designer, but he had great faith in horizontal castings.

The Future of Die Castings

MR. A. LOGAN said that most foundrymen were a little suspicious and scared of die casting and it was quite obvious that the wide sphere of die casting was not fully appreciated by them. Very often it was put on one side as something which was relatively unimportant and as something, as Mr. Faulkner had suggested, which was confined to the making of ash trays and novelty articles. That, however, was by no means the case. For some years now, die casting had been an expanding field and it was of tremendous importance in the motor vehicle and aircraft industries. A very large number of automobile parts were being die cast and the modern foundryman who did not take up die casting would have to look to his laurels. Some really large size castings were being made satisfactorily by die casting and one example was the landing wheels of aircraft which were being die cast in magnesium alloy. Until comparatively recently these were reckoned as being right out of die casting.

The question of nomenclature in die casting was quite important and in this country it should be easy to have two terms only. Everybody knew the difference between a die casting and a sand casting and it should only be necessary to specify whether the casting should be pressure die cast or gravity die cast. If these two terms only were used it should not be possible to go very far astray. Mr. Maybrey had made that obvious and had explained quite efficiently the considerations which determined whether an article should be die cast or not. In stating the advantages of die casting, however, Mr. Maybrey had omitted to mention speed of production, which was a vital factor. Taking an article weighing, say, 2 lbs., he did not know of any process of machine moulding which could equal the rate of production obtainable with die casting.

A point of some importance was the ratio of the total metal required to make a casting compared with the weight of metal in the finished article. This matter had been mentioned and, of course, it brought in quite a number of considerations. The whole crux of die casting was the question of the original design, and the design was fixed by the person who had to visualise the casting being made. Whether a job would be a commercial or a metallurgical success was governed fundamentally by the die designer or the casting designer, the person who studied the blueprints and decided on the way the casting should be made. This brought in the question of the total weight of metal used as a ratio of the weight of the finished article and he rather questioned the 10 to 1 ratio mentioned by Mr. Maybrey. It seemed to him extraordinarily high.

MR. MAYBREY agreed it was exceptionally high.

MR. LOGAN said he knew of a number of cases in which that ratio was half the figure mentioned, and of cases in which the runner and riser had to weigh half the casting. If logical principles were followed by foundrymen generally it should be possible to work with a very much smaller ratio than that mentioned by Mr. Maybrey. With certain exceptions it seemed to him that the die casting industry had been in the hands of people who really were not foundrymen. It seemed to have been developed by engineers, and when he had inquired into die casting he had been horrified and shocked to find the methods that were being adopted. To a large extent the work was being done in an absolutely improper manner and with an absolute disregard for all metallurgical principles and foundry principles. That was why he had stressed the importance of design. Even the most complicated die casting could be made sound, and there was more than one method by which good results could be obtained. On the other hand, there were probably 20 other methods which would give indifferent results, both economically from the production point of view, and also from the quality of casting point of view. He suggested to Mr. Maybrey that the large casting he had shown that evening was quite improperly made. (Laughter.) His experience had been that top pouring was a very valuable method of running a die casting, and it was one which would cut down the "as-cast" ratio to the finished casting considerably. The small casting with the runner and riser was an interesting case, as it showed how two designers, in a very simple case like that, would make it in entirely different ways. Certainly his own way would not be the way which Mr. Maybrey had shown. Personally he would turn the casting upside down and have a runner and riser for each of the feet and have alternate pouring. The die diameter must, as far as possible, be uniform, and by adopting that method the ratio of "as-cast" to the finished article could be reduced to about one-third that already mentioned.

MR. A. LADEVEZE disagreed with pouring the casting down from the top because of the dirt and inclusions which would get into the casting. In the case of the casting which had been mentioned, he saw no reason for altering the design at the moment because the production from that mould was perfectly satisfactory. All the castings obtained were good ones. He did not know of any principles that could be laid down for the design of a die because different people looked at the matter from different angles. The position was exactly as Mr. Maybrey had stated, and that was what had happened in the case of his own firm. One point that had been overlooked was the need for making the tools as simple as possible. It was possible to get a satisfactory casting from an expensive and complicated tool and, on the other hand, it was perfectly possible to make a much simpler tool and obtain equally good results.

Vote of Thanks

MR. V. DELPORT, proposing a cordial vote of thanks to Mr. Maybrey, said it had been a very great personal pleasure to himself to be present at that meeting, because he had known Mr. Maybrey many years ago, although, unfortunately, it was some years since they last met. He particularly liked the manner in which the lecture had been given. It had given rise to a most interesting discussion, and this type of meeting was an interesting experiment, because sometimes it was extremely difficult to start a discussion at the end of a long Paper which had been read through by the author. It was a considerable extra task for a man who was running a foundry and at the same time doing work of national importance to give a lecture of this type, and if for no other reason he knew his proposal of a cordial vote of thanks to Mr. Maybrey would be enthusiastically accepted.

MR. P. D. PINCOTT, who seconded the proposal, said he must plead complete ignorance of die casting. He had always looked on it as an abortion and quite remote from sand casting. Therefore, he had not interested himself very much in it. As regards Mr. Logan's remarks about top pouring, as one associated with sand casting, he agreed with top pouring as having a great deal in its favour, particularly where pressure work was concerned.

The vote of thanks was given with hearty acclamation.

MR. MAYBREY, expressed his appreciation of the vote of thanks.

Recent American Developments in Cast Iron

By A. B. EVEREST, Ph.D. (Member)

Introduction

It is not easy under present conditions to select a subject for a Paper. So much that is really interesting comes under the ban of the censor, or must not be discussed for reasons of national security. Foundrymen must therefore be patient, and look forward to a crop of really interesting disclosures after the war, when the inevitable developments under wartime conditions can be freely aired.

In the present instance, the above title for his Paper was selected by the author for a number of reasons. In the first place, under wartime conditions the question of availability of literature from abroad often arises. In view of the splendid work of the Navy and Merchant Service in keeping open the Atlantic, this difficulty has not arisen seriously in the present conflict with regard to U.S.A. publications, and it is truly remarkable to what an extent copies of the journals and other publications have been received regularly from the "other side." At the same time, however, there is another aspect of the problem, in that availability is limited, since extra copies cannot be easily acquired, due to international financial restrictions. In this connection it should be mentioned that this whole difficulty is being met very adequately by the excellent services of our British papers, especially the "Foundry Trade Journal," in giving a prompt review of the work received from abroad.

In the second place, it is felt that a review of recent American literature is justified, since many of those most directly interested are fully occupied with production and have not the time or facilities for studying a large volume of work for themselves.

The main reason for the author's selection of title, however, is something much bigger than the two factors mentioned above and it lies in a realisation that since the war began both the quantity and quality of published work which has reached us from the United States have been outstanding. It seems almost as though since mid-1939 the output of work on cast iron in America has been on a steady crescendo, reaching a climax in the A.F.A. meeting in New York in May, where it is believed more fundamental Papers on cast iron were presented than ever before at any one gathering.

It is the author's job to draw attention to some of the more interesting and important pieces of work published since mid-1939 and to do this a bibliography, covering several of the more important Papers, is appended.

It will be noted that many of the well-known American institutes and universities have participated in the output of work, apart from several of the research organisations associated with industry, as, for example, laboratories connected with the malleable trade and chilled wagon wheels, and also those with a more metallurgical interest connected with molybdenum or nickel. The work from these various organisations carries such well-known names as Boyles, Lorig, Timmons, Crosby, Herzig, Massari, Lindsay, Schwartz, Reese, Flinn and Eash.

The work published by these various people covers several aspects of cast iron development, including melting practice and superheating, alloying and inoculation, heat-treatment and malleablising and special studies of mechanical properties and standardisation.

Foundry Production

It will be realised that the developments of cast iron considered in this Paper apply to the constitution and properties of cast iron as such, rather than to any detailed consideration of the production or properties of particular castings. With this in mind, the question of foundry production is dealt with mainly under the heading of cupola control. A great deal of work has been carried out in the United States in connection with melting furnace operation, the object of a great deal of this being uniformity, and in this connection agreement is felt with the opinion expressed by Kayser at a recent London Branch meeting, when he emphasised that quality was in many respects synonymous with uniformity. It is felt that in the United States, factors tending towards uniformity are more in favour of the foundryman than in this country, owing to the substantially larger quantities of material handled under given conditions. Thus, it is felt to be a matter of general principle that a large cupola is more easily controlled to give a uniform product than is a small one and similarly more stable results will be achieved on a long run than on a short blow. Perhaps the greater tonnage output is partly responsible for the closer attention given to cupola control, but it is nevertheless remarkable that so much attention is given to factors such as blast weight or volume control, moisture control in the blast, temperature of blast, and control over charging operations, etc. A great deal of work has been carried out on cupola control by various organisations where special facilities are available. Some of this work is only now in course of publication, but the conclusion from one such piece of work known to the author is of special interest. This shows that with higher moisture content in the cupola blast, a higher carbon pick-up results, other things being equal. The work in which this conclusion is based will shortly be published and should prove of outstanding interest to the foundryman.

Other studies of cupola operation, especially in the production of high-duty cast iron, are given in Papers by Gillett[2] and by Roth,[3] in which latter the author describes the day-to-day production, and under ordinary foundry conditions, of an alloy cast iron, showing a tensile strength of over 27 tons per sq. in.

It certainly appears from these and similar publications as though in the United States the cupola is used for the production of high-duty cast iron generally to a greater degree than in this country. It is well known that in the U.S.A. extensive use is made of electric furnace melting, but it was the author's experience when last visiting the States, in 1937, that their cupola practice was far in advance of European and little use was made of the rotary furnace or air furnace, apart from the electric furnace.

Reference is made in recent American literature to electric-furnace high-duty irons, a notable case being in a Paper by Barlow.[14]

Grey Cast Iron

With regard to the study of grey cast iron generally, a number of Papers have been published. Throughout these there is a uniform trend to accept the fundamental principle that the properties of cast iron are determined:—(1) By the form of graphite, and (2) by the nature of the matrix of the metal. Some extremely valuable work has been carried out on the formation of graphite in cast iron (see the bibliography[8 9 10 11] appended). Attention is given in each case to the necessity for avoiding the formation of the so-called grain boundary or eutectic type of graphite, which, it is established by the various authors, forms due to the undercooling of the melt at the moment of solidification. Close attention is given to this by Boyles and Lorig,[11] whilst the other authors referred to above all give consideration to the method of solidification of cast iron and emphasise especially the need for inoculation of the melt in order to control the formation of graphite according to the austenite-graphite system, rather than according to the metastable austenite-carbide system. The theories put forward by the different authors explain a great deal, not only with regard to the formation of the undesirable grain boundary graphite structure, but also with regard to the effects of superheating and the general theory of inoculation. This whole aspect of the problem is admirably reviewed in the first part of the Paper by Flynn and Reese.[9]

Some of the latest American work emphasises that graphite form is of far greater importance than the quantity of graphite, and an interesting feature revealed by current American literature is the increased tendency towards high total carbon content in high-duty irons for applications such as brake drums, cylinder liners, etc., where the presence of a relatively large amount of graphite is useful either from the lubrication point of view or for resisting thermal shock.

Another interesting factor of the Papers mentioned above is that, in studying inoculation, the conclusion is reached that silicon is perhaps the most useful material for inoculating an iron which would tend to show undercooling, leading to weak graphite patterns. From the inoculation point of view, however, it is considered desirable in much of the American work to combine deoxidising elements with silicon.[12] A number of special inoculants is now on the market in the United States, some of them having fanciful names (one of which is a special "Vitamin B" dose for cast iron). Inoculation is, however, studied in some of the above Papers from the point of view of graphite liberation in the melt and ties up with the practice, which has previously been noted from the United States, of adding Mexican graphite immediately prior to casting.

Matrix Structure

A study of the various Papers recently published in the United States, dealing with the control of the matrix in cast iron, leads to the conclusion that alloying and heat-treatment are becoming more and more inseparably combined. A new feature in some of the American Papers on cast iron is the reference to "S-curves." Very briefly, an S-curve relates the length of time taken for the austenite transformation at the various temperatures below the critical. A typical S-curve is shown in Fig. 1. The exact significance of this curve will be appreciated if it be assumed that a piece of cast iron is soaked at a temperature above 750 deg. C. until the matrix of the metal is completely austenitic. The part in question is now cooled rapidly to a given temperature, say 600 deg. C., and held there. After a short lapse of time, measured by point A in Fig. 1, transformation of the austenite commences, and continues with time until at point B transformation is complete. If the same piece of iron had been cooled rapidly from the austenite range, to a temperature of, say, 350 deg. C., and the time taken for the transformation to commence and complete was again measured, then points C and D would be obtained. If this procedure were followed for all temperatures in the range from 750 deg. C. to room temperature, then curves as shown in Fig. 1 for the commencement and completion of the transformation will be obtained. It will be noted that the time scale in the curves is a log scale. Fig. 1 shows S-curves as for ordinary cast iron. It is now established, however, that the shape of the S-curve varies substantially with composition, and especially with alloy content. Furthermore, the shape of the S-curve is closely related to the structures which will be developed in the metal under given heat-treatment, since, as shown in Fig. 1, various structures are evolved by transformation of the austenite at different temperatures; thus, at point A, a pearlitic structure is obtained, whilst at point E a martensitic structure results on the rapid cooling of the specimen to a temperature of about 200 deg. C. At intermediate points, such as C, intermediate transformation products, such as "sorbite" or "troostite," will be obtained. With alloying, the shape of the S-curve is changed substantially and, generally speaking, the whole curve is pushed over to the right. An indication of the effect of alloying on the shape of the curves for the commencement of transformation is given in Fig. 2.

The whole S-curve technique was evolved in the first place by Bain, in connection with alloy steels. It is, however, now being extensively applied to cast iron in explanation of the modification of structure by alloys and heat-treatment. Thus, for an addition of nickel, the first high-speed transformation, represented at A in Fig. 1, is pushed over to the right so that, whilst ordinary cast iron would transform to pearlite, with nickel cast iron a normal cooling rate may be too fast for the pearlitic transformation to get started. In this case, the austenite transforms at the lower temperature ranges, and an iron with a martensitic matrix results. The influence of alloy additions on the S-curves is dealt with at some length by Flinn and Reese.[9]

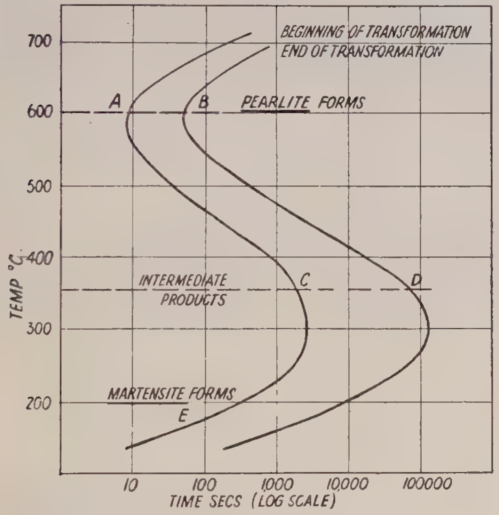

FIG. 1.—S-CURVES FOR AN ORDINARY CAST IRON.

Heat-Treatment

The S-curves are of greater interest, however, in connection with developments in the heat-treatment of the cast iron. Bartholomew[16] in 1940 published details of a special patented heat-treatment for improving the properties of iron castings. The method of heat-treatment described by Bartholomew is now well-known in the United States under such names as the "hot-quenching" of cast iron, the "isothermal treatment" of iron, or as "austempering." This heat-treatment, which can be applied to all ferrous materials, is based on the S-curve. Previously, if an iron of improved quality and wearing properties was desired, it was usual to apply a quench in a cold medium, followed by tempering. By the isothermal treatment now recommended, equally good or superior mechanical results can be achieved by quenching the article directly into a salt or metal bath, held at a moderate temperature, *e.g.*, in the range of 200 to 300 deg. C., and which gives a direct breakdown of the austenite to martensite or an intermediate product. The great advantage of this treatment is that it overcomes the difficulties and dangers associated with the quenching of complicated parts under conditions liable to cause fracture or cracking, and undoubtedly isothermal treatment is a substantial advance in cast-iron metallurgy, and will be of great value and service in the future.

Bartholomew[16] in his Paper gives details of the isothermal quench, and shows that substantial advantages are obtained by quenching plain and alloy cast irons from about 850 deg. C. in a bath at 266 deg. C., and after holding at that temperature for 15 mins. the parts in question are slowly cooled.

Another important Paper dealing with isothermal treatment is that by Nagler and Dowdell.[17] A further interesting point is the development, especially by means of molybdenum additions to cast iron, of the so-called acicular structure. Flynn and Reese[9] deal extensively with the development of this structure by alloying, and also refer to its formation in relation to S-curves.

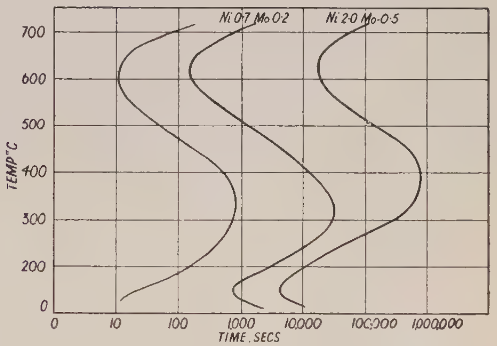

FIG. 2.—EFFECT OF ALLOYING ELEMENTS ON THE SHAPE OF S-CURVES.

Alloy Additions

Although a considerable amount of work has been carried out in the United States on alloy additions, there is perhaps in this direction less fundamental change in the position than in other aspects of iron foundry metallurgy. The outstanding results achieved with combinations such as nickel and molybdenum were recognised before the war and, as is only to be expected, the work[19] of Timmons, Crosby, Herzig and Young of the molybdenum laboratories has continued. Extensive reference is also made in American literature to the production of high-duty cast iron with other alloy additions, including copper, etc., and it now appears from these references that it is general practice for cast iron to be produced to specification grades higher than anything visualised in this country up to the present. In addition to the usual strengthening elements, work has also been carried out with other additions, including elements such as vanadium, tellurium and boron.

Flame Hardening

The Americans have given detailed attention to the flame hardening of high-duty castings, especially for machine tool production, and in this connection have published a certain amount of information based on their experience. Those interested in this aspect of the treatment of iron castings would be well advised to refer to the Paper by Sefing[23] and a long series of articles by Hartley,[24] who studies the question of standardising all the factors involved in flame hardening. As in the case of many other problems, satisfactory results have been achieved by flame hardening on a production scale, when the volume of work to be turned out is sufficiently great to justify a complete standardisation of all the various factors and variables involved. Other Papers, of perhaps less importance, deal with more specialised applications of flame hardening, as, for example, to lathe beds.

The properties resulting from flame hardening appear to be of an extremly high order, and the general conclusion seems to be that alloy high-duty cast iron should be used, since with alloys a greater response and uniformity of result is achieved with minimised distortion, or alternatively a given result may be obtained with a milder heat-treatment.

Properties and Standardisation

As would be expected in parallel with the various Papers mentioned above, there have been a number of investigations described in the Press, dealing with the special properties of cast iron. Some of these are of a very advanced nature, as, for example, in the case of the Paper by Collins and Smith[26] on the high temperature fatigue properties of cast iron.

A very useful collection of data on cast iron related to the various strength grades covered by the U.S. Specification A.48-36, is contained in a publication on the engineering properties of grey cast iron.[21] Whilst this publication does not draw any extensive general conclusions, it gives a mass of data on particular irons relating the ordinary and some special mechanical properties with chemical analysis and method of production. This publication is of special value to anyone studying the more unusual properties of cast iron.

With reference to standardisation, the Report of the A.S.T.M. Committee A.3[22] is particularly interesting. It reviews the present standardisation position for grey cast iron, and mentions particularly that attempts are being made to standardise impact testing in the United States. The basis of this standardisation is a drop test and the Charpy test. The outstanding feature of this Committee's report, however, is the publication of a proposed standard for graphite form and size, together with tentative recommended practice for polishing and measuring graphite flake size. It is felt that this standard would be of particular value, and should receive a considerable amount of attention, even in this country.

Malleable Cast Iron

The most interesting development in recent American literature on malleable is related to the production of pearlitic maleable prepared by the short cycle annealing process. A Paper fundamental to this process is that by Ziegler, etc.[7] These authors have studied the decomposition rate of cementite, both above and below the critical temperature. They point out that decomposition of primary cementite is rapid at temperatures well above the critical, but is incomplete. Graphitisation of all the primary and excess carbon held in the austenite matrix can only be completed at temperatures just above the critical. Second stage graphitisation progresses most rapidly and completely simultaneously with the formation of pearlite, and they conclude that the most efficient method of graphitising cast iron is therefore to carry it out in steps, combining speed of decomposition with maximum possible graphite formation at each temperature range. Other Papers of fundamental interest in connection with malleable production are given in other references,[27-30] whilst a point of special interest is brought out in the Paper by Cowan,[31] in that he applies austempering to pearlitic malleable cast iron with interesting results. Smith[25] shows that flame hardening can also be applied to malleable castings of correct structure.

Conclusions

This review of American literature since the outbreak of war is necessarily very sketchy and must be regarded as incomplete. The bibliography of reference includes only those Papers which have come to the author's notice and which seem to him to be of outstanding interest to British foundrymen at the present time and, as already mentioned, the selection does not include any Papers referring to the production of castings. Enough has been said above, however, it is felt, to show that American metallurgists are at the present time very actively engaged in studying fundamental problems on cast iron and have succeeded in producing many new facts and theories, all of which help towards the production of ever better products.

Finally, the author would like to record his indebtedness to his colleague, Miss E. W. Parker, who from her technical records was able rapidly and efficiently to turn up some fifty or sixty references to foundry developments in the United States in the period under review.

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DISCUSSION

The BRANCH-PRESIDENT (Mr. R. B. Templeton), in opening the discussion, commented on the possibility of reduced cost through the adoption of austempering for cast iron.

" S " Curves

MR. V. C. FAULKNER (past-President), discussing the problem of inoculation, said he gathered that speed was essential; it seemed necessary to cast very soon after inoculation. He asked whether plant had been installed in this country for the " austempering " or the isothermal treatment of cast iron. Such treatment was being applied here to steel. Finally, he said that Dr. Everest's remarks had given him a better appreciation than he had had before of the " S " curves, and he looked forward to a closer study of the subject.

DR. EVEREST replied that the " S " curve theory was explained in the Paper by Flynn and Reese, which was most fascinating. Endorsing Mr. Faulkner's remark with regard to the importance of casting soon after inoculation, he said it was recognised nowadays that when cast iron was inoculated its ability to form the required type of graphite, conferred by the inoculation, faded away within a short space of time. It was necessary, generally, to cast within 10 or 15 mins. after inoculation. He did not think the isothermal treatment of cast iron was being practised in this country yet.

Dry Blast for Cupolas

MR. A. LOGAN (past-President, Newcastle Branch) said he had been impressed by the growing worth of American research on cast iron. It was a somewhat remarkable tendency, and he had been rather at a loss to find a reason for it. It was true that uniformity meant the maintenance of quality; indeed, the whole object of foundry control was to secure uniformity and to be able to maintain the production of good quality castings.

Another factor which had impressed him was the amount of attention which had been devoted to the pre-drying and pre-heating of the blast to the cupola, and there was a very great need for it. In this country there was a wide variation in the moisture content of the atmosphere as between the different seasons and even from day to day, and with those variations of the condition of the atmosphere there were differences in the operation of the cupola; so that that factor was also important in securing uniformity of product. Founders in this country were bound to devote a great deal more attention to it, and in the near future members might hear of foundries adopting the pre-drying and pre-heating of the cupola blast.

With regard to the point that the carbon pick-up was high when the moisture content was high, he said he had not previously appreciated this fully, but it seemed quite likely. He asked what were the reasons for it, and what was the extent of the extra carbon pick-up as the moisture content increased.

Discussing superheating and inoculation, he asked for some elaboration of the point that the higher degrees of superheat did not confer improved physical properties. Those who studied cast iron, he continued, must be intensely interested in graphitisation, which was another factor closely concerned with control. In the course of some work on the subject some years ago he had rather gained the impression, though he could not positively confirm it, that it was quite possible to have two cylinder irons, for example, each containing 3 per cent. of graphite by weight, but whereas in the one case that 3 per cent. by weight represented 10 per cent. by volume, in the other case that 3 per cent. by weight might represent much more than 10 per cent. by volume. He asked for Dr. Everest's comments on that matter.

In the course of the work to which he had referred he could not be quite certain that the sizes and shapes of the graphite flakes as seen under the microscope—with their resulting area and computed volume—correctly represented the graphite as existing in the structure. Nowadays, with the improved polishing technique available, one could be much more certain. He had not had an opportunity of reviewing the matter recently, and the impression he had formed earlier might not be justified. The point was important, as, if correct, it would indicate a possible variation in the specific gravity of the graphite, or some gas reaction or gas liberation coincident with graphitisation.

Superheating and Graphitisation

DR. EVEREST, replying to Mr. Logan's question as to the incentive for the great amount of research work on cast iron in America, said that in the first place the industry in America was backed by an extremely active Association. The latest issue of the house organ of the American Foundrymen's Association contained the lists of the committeemen appointed for the ensuing year. There were about 90 committees, and the list of names of the members of those committees filled many pages. Thus, the work was distributed among a great many extremely enthusiastic people. That enthusiasm had spread, obviously, to those who were studying for higher degrees at the universities, and that explained some of the university work. Further, there appeared to be competition between the various research institutes to turn out the best work. In the past, perhaps, the public had not given a great deal of attention to some of the American work; but the quality of such work had improved enormously during recent years as to warrant intensive study.

With regard to the control of moisture content in the blast to the cupola, he said he had seen the Paper which dealt with the subject and the main conclusion was that the carbon pick-up increased with increased moisture content. Surely, he continued, the fundamental principles in regard to the blast would be the same in cupola practice as in blast-furnace practice, and he knew that the silica gel process was used in this country for the drying of the blast in blast-furnace practice. No doubt the Papers which had been presented to the Iron and Steel Institute in this country would throw light on the subject. The broad idea was that, in the burning of a certain weight of coke, if a large proportion of moisture in the blast had to be heated and evaporated, that represented waste of heat. The result, therefore, was to slow up the rate of melting, and the charge was in contact with the coke for a longer period, so that there was increased carbon pick-up. That explanation might be right or wrong, but, at any rate, had the merit of being simple.

With regard to superheating, he said the point was that if there were any graphitising tendency or inoculants present in the molten iron, whether they were there initially as added inoculants or whether there was some tendency inherent in the metal itself, then, as superheating proceeded, that tendency was suppressed; so that the higher the temperature to which the material was superheated before casting, the greater was the tendency to under-cooling, and the under-cooled structures were the iron carbide structures, which broke down to grain boundary graphite. In those weaker structures the inoculation effect had been wiped out by superheating.

Discussing Mr. Logan's reference to graphite standardisation, Dr. Everest said that in the A.S.T.M. specification a method of polishing specimens was recommended. He suggested that possibly the effect which Mr. Logan had noticed, where a given graphite content by weight might appear to represent different percentages by volume in different irons, might be due to the fact that, in the course of polishing, relatively large holes were torn in the metal surfaces, and those surfaces appeared to contain more graphite than in fact they did contain. The leading exponents of the art of polishing were the workers in the British Cast Iron Research Association, and in their excellent work they had shown that the black spots that appeared on the surfaces were not necessarily all graphite flakes.

American Technical Progress

MR. V. DELPORT (past-Branch-President), confirming the remarks of Dr. Everest concerning the great attention given by the American Foundrymen's Association to cast iron research, pointed out that the interest shown by the Americans in cast iron research was not new. The Transactions of the Association covering quite a number of years showed that at the Annual Conventions of the Association year after year there were presented anything from 20 to 40 Papers, mostly devoted to cast iron, sand, and so on. Perhaps one reason why it had been thought that the quality of the Papers presented in the past was not so good as it might have been was that the quantity was so considerable. Out of 40 Papers there might have been only half-a-dozen which were really outstanding. Again, only comparatively recently had some of the research work of the past 20 years or so begun to yield interesting results; that work was giving nowadays data on matters which were not even thought of 20 or 30 years ago—and, indeed, that was true also of other countries, including Great Britain.

Relative Value of Graphitisers

MR. E. M. CURRIE said he had not intended to cross swords with the author, but felt he must do so with regard to the use of calcium silicide and the wearing off of the effects of ladle graphitisation within a comparatively short time.

He believed that the Paper referred to by Dr. Everest, on the effects of ladle inoculation, was one published by the A.F.A. quite recently, and he had gathered from that Paper that the work described was done with ferro-silicon and not with calcium silicide. Apparently the experiments were made on very low carbon irons, containing from 1.74 to 2.37 per cent. T.C. Ferro-silicon was found to be more effective in those irons of low total carbon content than in those containing about 3 per cent. T.C. It had also been found that low silicon contents were necessary in low-carbon irons in order to avoid weak dendritic structures. Again, with regard to the statement that the " inoculation " effect wore off after the ladle had been standing for from 15 to 18 mins., he said he had not specially attempted to find out whether that was strictly true, but he had rather gathered, from his own experiences, that very different effects were obtained according to the types of graphitisers used. The graphitisers included silicon, nickel, zirconium, calcium silicide, and so on. There was a tendency for the effect of graphitisation with silicon to be irregular. Test ladles taken from the top and the bottom of the main ladle showed different results. He had not, however, found so great a difference when using calcium silicide; and he imagined that the effect of nickel on graphitisation would not be variable to the same extent as that of silicon.

Pearlitic Malleable

The use of pearlitic malleable appeared to be extending in America, and some extraordinarily interesting results had been achieved. In this country we were merely playing with the idea so far; but for the ordinary grey iron foundry, making the hard, white type of iron, it appeared to be an extremely interesting and useful field of experimentation. Recently he had seen one of these pearlitic malleables produced in a grey iron foundry without any real difficulty at all. The total annealing time was 26 hrs., and the iron produced gave about 22 tons per sq. in. tensile, 5 per cent. elongation and, using a test-bar of 1-in. dia., gave an Izod impact value of 120 ft.-lbs., which was exceptionally high.

From a report he had received of a recent foundry meeting it appeared that many present had boasted of the poor quality materials they had used to produce exceptionally good high-duty irons. He hoped that that impression would not gain ground in this country, lest there should be a repetition of the experience of difficulties such as had occurred in another connection about the period 1923-25; at many foundry technical meetings in the Midlands at that time people had boasted about the very low coke ratios they had been able to adopt for melting iron, and in his opinion they had caused a great deal of harm in the industry.

Ladle Metallurgy

There had been some interesting developments in America concerning ladle metallurgy, involving the use of materials known as Chrome-X, Silicon-X and Copper-X. There was quite a field for interesting experiment in that direction, because by such additions one could produce small quantities of high-alloy irons in a simple way. In one report it was stated that, to a 200-lb. ladle, there was added about 5 lbs. of Copper-X, 8 lbs. of Chromium-X, and 23 lbs. of Silicon-X to produce contents of 1½ per cent. copper, 2 per cent. chromium, and 4½ per cent. silicon. The percentages recovered were remarkable, being about 85 per cent. of the copper, 77 per cent. of the chromium, and 99 to 95 per cent. of the silicon. The temperature rise at the end of the operation was of the order of 25 to 30 deg., instead of the usual temperature drop when adding normal ferro-alloys.

Influence of Time on Graphitisation

DR. EVEREST, replying to Mr. Currie's question concerning inoculation, said that Boyles and Lorig in their Paper had described how they had inoculated a bath of iron and had made the first cast 2 mins. after inoculation, and then had held the metal in the bath for half an hour before making the second cast; in that experiment they had used calcium silicide. Eash had not used calcium silicide, but had used combinations of silicon and nickel; Dr. Everest said he had only quoted the conclusions arrived at by Eash concerning the effect of under-cooling. It was still rather difficult to discuss the mechanism of inoculation, but he believed that a low-carbon iron required inoculating more than a high-carbon iron in order to ensure avoiding dendritic graphite.

MR. CURRIE said the basis of the original work on the high-tensile irons was to work with a low-carbon, low-silicon, iron which would ordinarily cast white, but to inoculate it and so to throw it over to the graphite condition in order to produce the improved properties.

DR. EVEREST was not sure that that was altogether the explanation. He felt that the Paper from the Battelle Memorial Institute, on under-cooling, referring to the shape of the graphite flakes rather than to a composition which would be classed as that of a hard iron, gave a little more information on the strength of high-duty irons. One found only too often that two irons of similar composition gave totally dissimilar physical properties. The Battelle Institute workers had experimented with an iron of about 3 per cent. carbon, 2.2 per cent. silicon, and 0.7 per cent. manganese, with and without graphitisers. Both samples began to freeze at about the same temperature, 1,100 deg. The eutectic freezing point was about 1,130 deg., and the rise of temperature in the processed sample was less than that in the un-processed. There was something in that question of the reduction of the latent heat and its effect on the micro-structure. The un-processed iron seemed to give the graphite in rosette form, whereas the processed iron gave it in randomly distributed form. There was probably a greater field for exploration among those micro-structures than had yet been realised.

Effect of Temperature

MR. C. H. KAIN (past-Branch-President), referring to his personal experience of inoculation or ladle processing, said that the effect of the inoculation or processing did wear off, but much more rapidly at high temperatures than at low temperatures. Therefore, when discussing ladle processing, it was most important that the temperature of the iron should be stated. He asked whether any information had been published recently concerning the fluidity or flowing power of the processed irons, because that property varied tremendously. That again was closely allied with the question of temperature; but, in his experience, the irons treated with metallic silicon tended to become very sluggish or, in other words, to lack fluidity.

With regard to the "S" curves, he said he understood that a little work had been done in this country on that very interesting development, in respect of both steel and cast iron. It was well worthy of close study, and he asked if Dr. Everest would confirm that the work mentioned had referred entirely to irons which had been heated to a high temperature and were being cooled or quenched, *i.e.*, that it referred to cooling curves and not to heating curves.

Discussing superheating and its effect on structure, Mr. Kain commented that insufficient attention was given to the conditions following superheating. If the pouring temperature of the iron rose much above the freezing point, the cooling conditions surrounding the test-bar from which the results were taken, on the casting, varied tremendously. The problem of the velocity of cooling had not been studied sufficiently. In the course of experiments made some years ago, it was shown that superheating so affected the cooling velocity at various stages that it was possible to produce mixed structures of coarse graphite, supercooled graphite and white iron.

Just before the war the Steel Castings Committee of the Institute was collecting data on the physical properties of cast steels, and had found that the physical properties, particularly the impact values, were increased very greatly by very rapid heating in the normalising or annealing process. He believed Mr. Deschamps had collected considerable data on that matter, but did not know whether or not that data had been published.

Quick Anneal of Malleable

DR. EVEREST, replying to the Branch-President's remarks on isothermal treatment, stated that the chief advantage of this is that it was more foolproof than the ordinary quench and temper treatment. Controlled heat-treatment furnaces for the heating of the materials to a given temperature were, of course, required, and then a quenching bath at a controlled temperature. The equipment and expense involved were therefore not substantially less than for the more normal treatment.

Replying to Mr. Kain's question concerning fluidity of the processed irons, he said there was some information on the matter in the American Papers he had studied, and he would indicate it in the bibliography published with his address.

He believed that the process for the rapid heating of malleable had not yet progressed very much in this country, because of the equipment costs. The equipment, which included a conveyor type of furnace with properly controlled temperature zones, was fairly expensive, and the Americans adopted it only in association with very large production.

Impact Testing

MR. T. W. RUFFLE, who commented that Dr. Everest's clear explanation of the "S" curve technique qualified him for appointment to the Brains Trust, asked whether any large-scale work had been done in connection with impact testing.

DR. EVEREST replied that the Americans had been endeavouring to standardise the Charpy test. In the Report of the A.S.T.M., which referred to the work of the various committees of that society on cast iron and other materials, it was stated that Sub-Committee XV, after having studied for some time the drop test method and the Charpy impact test, had concluded that both those methods needed to be standardised tentatively for purposes of research and the accumulation of data for inclusion in future specifications. The Report included details of both tests. Others in the United States had developed a modified Izod test to some extent, but it appeared that they had not continued the work very far, and he believed that attention was being devoted more and more to the Charpy test. A committee of which he was a member was pursuing the modified Izod test in this country. In reply to a question, he said the committee had not standardised that test, but was studying its possibilities.

MR. RUFFLE asked how the grooved bar was mounted.

DR. EVEREST replied that the centre line of the groove should be level with the top of the vice. However, one should not regard that test as standard, or adopt it, until more information had been published about it, because it might have to be abandoned for other methods.

MR. RUFFLE, referring to uniformity of product, pointed out that sustained mediocrity was better than occasional perfection.

MR. TEMPLETON expressed the hope that someone would suggest a word which could be substituted for "inoculation," for he did not think it was a suitable word to use for the process referred to.

Vote of Thanks

MR. CURRIE proposed a hearty vote of thanks to Dr. Everest for his most instructive address, which was a mental stimulant to all who had heard it; it would give rise to a great deal of thought on matters which one was apt to forget in the present rush for higher production.

MR. LOGAN, who seconded, said it was a privilege to listen to the address, and he expressed gratitude to Dr. Everest for having spared the time to prepare and deliver it.

DR. EVEREST responded to the vote of thanks, which was heartily accorded.

Scottish Branch **Paper No. 763**

Foundry Production Problems with Special Reference to High-Duty Alloy Cast Iron

By A. E. McRAE SMITH, M.A. (Member)

The subject chosen is rather a thread-bare one, since so much has been written about high-strength and special-duty cast irons in the last few years. There are two main fields covered by these cast irons, the first relating to really high-strength material and the other to cast irons of special composition for special purposes where their particular properties, such as resistance to corrosion, resistance to wear and resistance to heat make them particularly suitable. The latter class of cast irons may be of comparatively high alloy content, such as austenitic cast irons, high-silicon, high-chromium and even high-tungsten cast irons, whereas high-strength cast irons are usually of low alloy content. The properties of all these types of alloy cast iron depend largely on the kind of structure produced rather than the actual quantity of the alloying elements present.

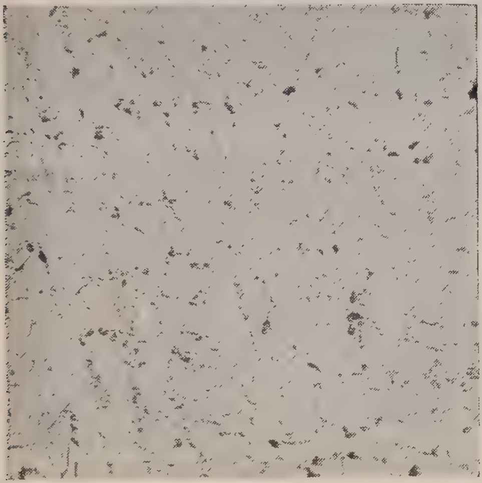

FIG. 1.—SHOWING EUTECTIC OR GRAIN-BOUNDARY GRAPHITE. (× 100.)

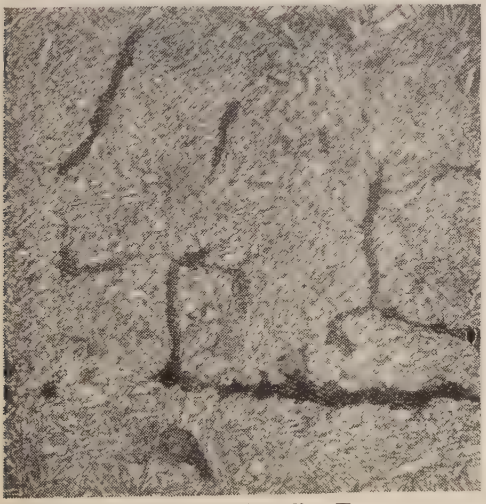

FIG. 3.—(SAME AS FIG. 2). TEMPERED. (× 500.)

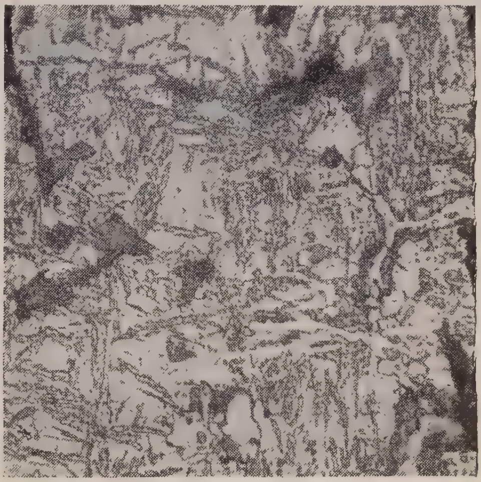

FIG. 2.—ACICULAR-STRUCTURED NI-MO CAST IRON FROM CRANKSHAFT CASTING, AS CAST. (× 500.)

Inspection

It is not intended to deal in great detail with the metallurgical and compositional aspects of high-strength cast irons, but rather to discuss elementary principles and tendencies in foundry technique, which will ensure the production of really sound castings. Inspecting bodies have not seriously applied the art of radiology for proving complete freedom from defects in grey-iron castings of any category. No doubt this,

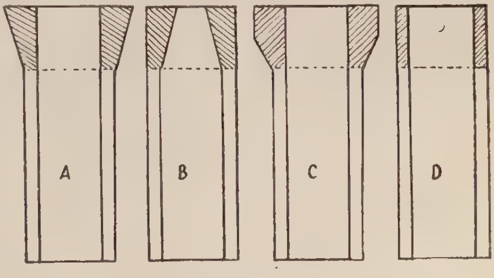

FIG. 4.—TYPICAL FEEDING HEADS FOR SLEEVE CASTINGS. A, B AND C—SATISFACTORY. D—UNSATISFACTORY.

or similar developments, will ultimately have to be faced by iron foundries, and castings, which to all intents and purposes appear to be completely sound either in the as-cast condition or even after deep machining, might not be acceptable for really severe service if underlying defects were revealed by radiology or other method of internal inspection, as is done with certain types of steel castings and more frequently with aluminium and magnesium alloy castings.

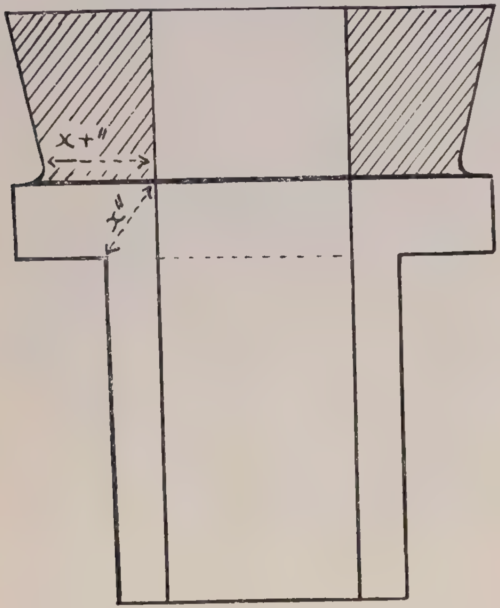

FIG. 5.—TYPICAL FLANGED BUSH OR LINER WITH FEEDING HEAD (SECTION THROUGH CENTRE). NOTE: DIMENSION *x* + ″ MUST BE GREATER THAN *x*″ TO ENSURE PROGRESSIVE SOLIDIFICATION.

At the same time, it is incumbent on the foundry industry to remember that, when producing high-strength iron castings, it is essential that the mechanical properties should be as nearly consistent as is possible throughout the whole mass of the casting, whether it is of light, medium or really heavy sectional thickness.

This question of complete soundness and freedom from liquid shrinkage defects in high-strength cast iron becomes more and more important as the duty demanded from such castings becomes more arduous.

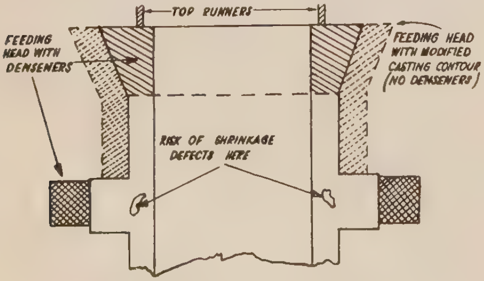
TOP RUNNERS
FEEDING HEAD WITH DENSENERS
FEEDING HEAD WITH MODIFIED CASTING CONTOUR (NO DENSENERS)
RISK OF SHRINKAGE DEFECTS HERE

FIG. 6.—TYPICAL GLAND RING CASTING (SECTION THROUGH CENTRE).

When dealing with low-strength grey-iron castings exhibiting mechanical properties in the range of 11 to perhaps 16 tons per sq. in. tensile strength, minor unrevealed liquid shrinkage defects are not nearly so disastrous, provided the castings are pressure tight, as is the case when

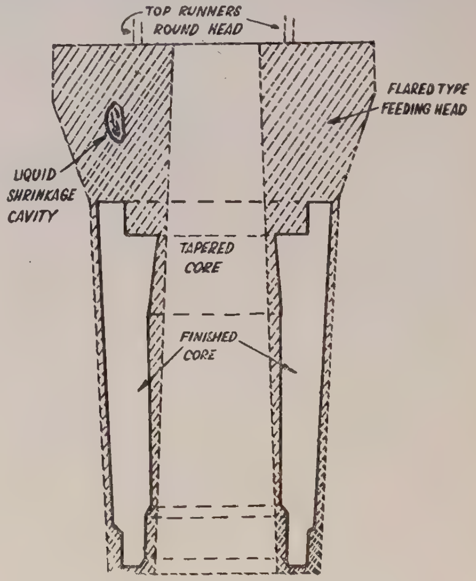

FIG. 7.—PIERCING POT DIE FOR HOT STEEL FORGINGS (LONGITUDINAL SECTION). DIE POT IS CAST VERTICALLY WITH HEAVY SECTION ON TOP TO PROMOTE PROGRESSIVE SOLIDIFICATION.

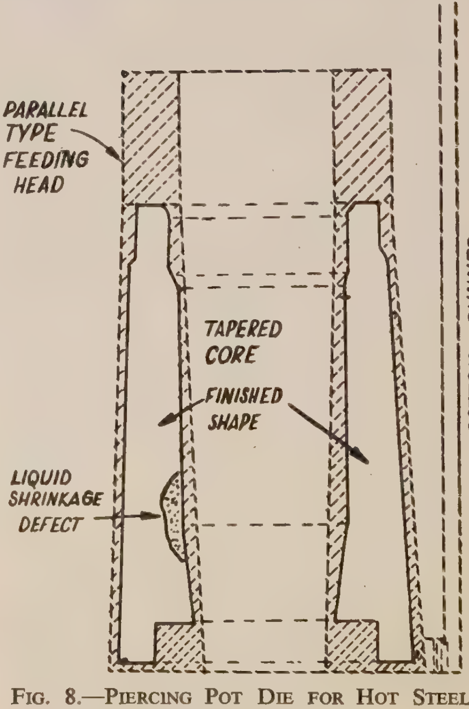

FIG. 8.—PIERCING POT DIE FOR HOT STEEL FORGINGS (LONGITUDINAL SECTION). UNSATISFACTORY METHOD.

the material has to exhibit mechanical properties in excess of the highest British specification, namely, B.S.S. 786, Grade 4.

Before discussing ways and means of ensuring that all castings leaving a foundry after effective scrutiny by Inspection Departments are really 100 per cent. sound, a few brief remarks on the types of cast iron and the processes used for the manufacture of high-strength castings may not be out of place.

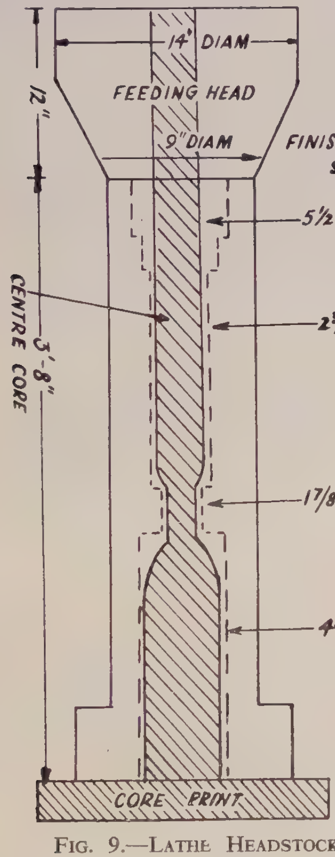

FIG. 9.—LATHE HEADSTOCK SPINDLE.

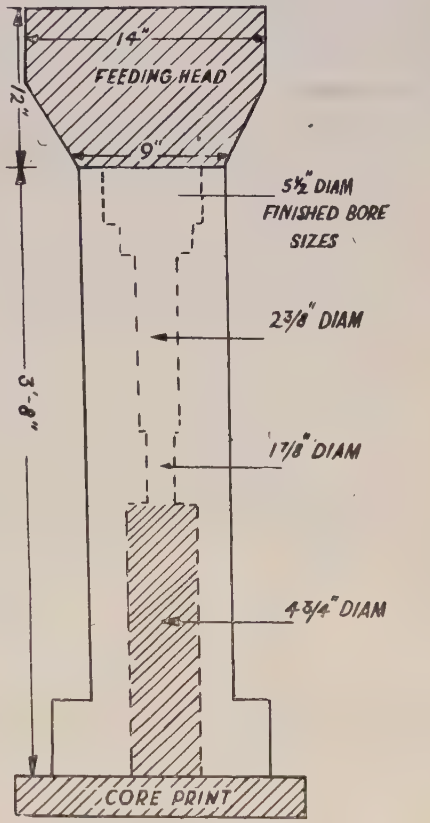

FIG. 10.—LATHE HEADSTOCK SPINDLE.

Inherent Difficulties

A good deal has been heard in recent years about the manufacture of alloy iron castings, and it is also very common knowledge that alloy additions normally react in two distinct ways. At one time some attention was given to the effect which such alloys have on the matrix of any particular type of cast iron, but latterly equal and perhaps more attention has been given to the production of cast iron with graphite structures which will have the least possible weakening effect on a high-strength matrix. In other words, it is useless to produce a cast iron with a matrix probably with a tensile strength of 40 to 50 tons per sq. in., but in which the amount of free carbon, as well as its size and arrangement, is such as to produce a material which, in its final form, has very poor mechanical properties indeed. Theoretically the alloying of cast iron should produce a matrix with equal mechanical properties to those of a steel of similar composition, neglecting the carbon content. This, of course, does not take place in actual practice, because cast irons always contain free graphite. If this free graphite is also in the form of very large flakes, then the difference between the potential and actual strength of the matrix will be much greater than would be the case with a similar amount of graphite in small flakes. However, this is not the whole answer, because it is found that most high-strength grey cast irons with a total carbon content under 2.7 per cent. very often do not give the anticipated mechanical properties. It is obvious that in grey cast iron, provided all other conditions such as base composition, alloy content, mass, sectional thickness, rate of cooling, casting temperature, etc., are equal, the actual tensile strength will depend on the total carbon content. The higher the total carbon content and, therefore, the greater the amount of free graphite present, the lower will be the strength. In point of fact, this does not always work out according to plan in actual practice, because it has been found by long experience that in the lower range of carbon content, say under 2.7 per cent., cast irons are prone to exhibit a graphite arrangement which has been variously described as eutectic graphite or more recently "grain boundary" graphite. When this type of graphite arrangement is present in a casting, it is a well-known fact that the mechanical properties are always very much inferior to those containing the same amount of free graphite, where it is arranged in random patterns.

Discussion of this subject in any detail is far beyond the scope of this Paper, but avoidance of eutectic patterns or grain boundary graphite is the very first essential for the production of really high-strength cast iron. The importance of this was very well illustrated by a number of papers on the subject of graphitisation and the general behaviour of graphite in cast iron given before the American Foundrymen's Association at the Annual Convention during May, 1941. It would repay any foundryman specially interested in the production of high-strength cast iron to peruse very carefully these Papers. Perhaps the most important, and from the foundryman's and metallurgist's point of view the most illuminating, is that entitled "The Development and Control of Engineering Grey Cast Irons," by R. A. Flinn and D. J. Reese.* This Paper deals very fully and very effectively with the properties and control of graphite structures in grey cast iron. In brief, the authors show that the structure of grey cast iron must be considered from two aspects, namely, (1) the graphite flakes, and (2) the matrix. They show that the amount of graphite will have a decided effect on strength properties and that one of the most important points about graphite is its distribution or arrangement. They emphasise the poor properties associated with so-called eutectic graphite, and conclude that the most favourable properties are always shown by irons with evenly distributed, fairly fine graphite in random formation. They also give very lucid and conclusive proof how these two forms of graphite tend to be produced.

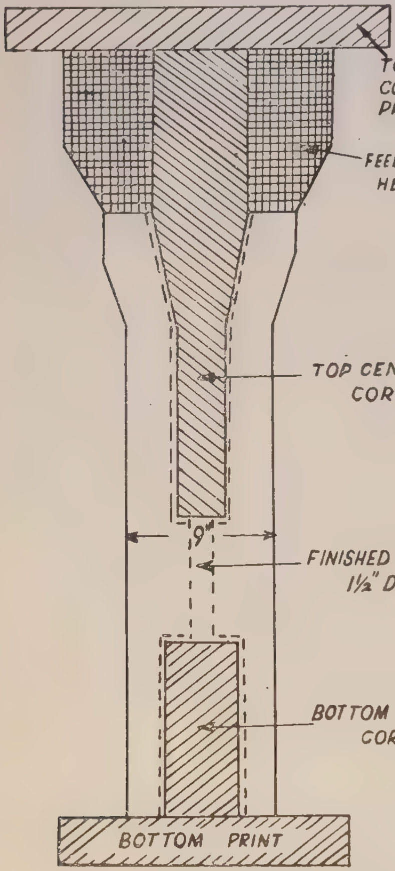

FIG. 11.—LATHE HEADSTOCK SPINDLE.

The *appearance* of typical "grain boundary" and random type graphite formations is, of course, familiar to most, but the following typical examples may serve to refresh one's memory. Fig. 1 shows so-called eutectic or grain boundary graphite producing a very weak structure. The graphite flakes in themselves possess very poor mechanical properties, and it cannot be too strongly emphasised that it is useless to endeavour to produce a high strength cast iron by strengthening the matrix if the graphite distribution is unsuitable.

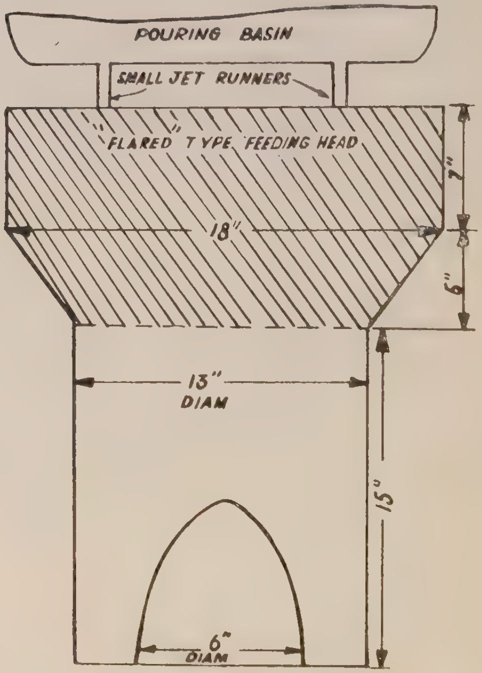

FIG. 12.—TYPICAL HOT HEADING DIE. METHOD OF CASTING NO. 1 (SECTION THROUGH CENTRE).

Economic Production

This leads naturally to discussing briefly the best and most economical methods of producing cast irons with high strength matrix structures. It is not intended to discuss cast irons with intermediate mechanical properties such as comply with the minima laid down for grades 1 and 2 of B.S.S. 786, but rather to consider, in a very general way, suitable compositions for cast irons to meet Grades 3 and 4, and more particularly those with mechanical properties considerably in excess of Grade 4.

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* A.F.A. Preprint No. 41-14, see also "Foundry Trade Journal" of January 8, 15 and 22, 1942.

The usual method of producing cast iron to meet the requirements of Grade 3 is to adopt one of the special process cast irons, usually with a total carbon content in the range of 2.7 to 2.9 per cent. with suitable alloy content. This alloy content usually consists of one or more of the following elements, namely, copper, nickel, chromium and molybdenum, either individually or in combination. All foundrymen are to-day acquainted with these cast irons, the most common types of which are those manufactured by the inoculation processes, such as Ni-Tensyl iron and the higher grades of Meehanite. Their production in the foundry calls for accurate metallurgical control, so that a correct carbon/silicon ratio may be maintained for any particular range of alloy content in order to ensure that the amount of combined carbon will be somewhere between 0.7 and 0.9 per cent., so as to promote fully pearlitic structures. Another variable, of course, is always present, namely, the cooling rate of the casting which will vary very widely with the mass and sectional thickness of different castings. Everyone is familiar with the mechanism of arranging percentages of total carbon, silicon and the alloy composition to suit different sectional thicknesses. If the carbon/silicon ratio is reasonably correct, the castability of these irons is good, but when the total carbon content approximates the lower figure, namely, 2.7 per cent., or may in fact be less than that, then their liquid shrinkage characteristics are not so good. It will be shown later how foundry technique must be adjusted to overcome this. Of the common alloying elements, it is well known that molybdenum is the most effective in increasing the tensile strength of grey pearlitic cast iron. This element is much more expensive than either nickel, copper or chromium, and consequently the special process irons, such as Ni-Tensyl iron and Grade A Meehanite, can be more cheaply produced than alloy cast irons containing molybdenum.

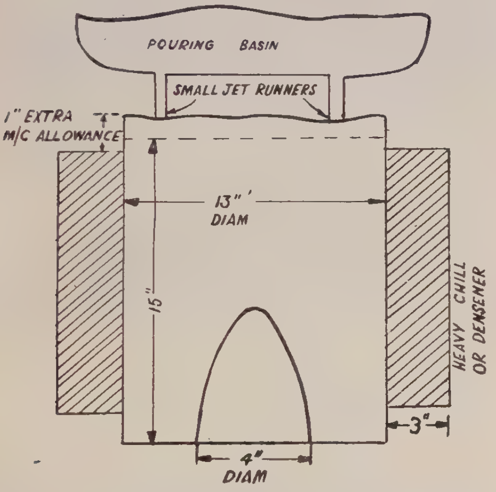

FIG. 13.—TYPICAL HOT HEADING DIE. METHOD OF CASTING NO. 2 (SECTION THROUGH CENTRE).

Molybdenum Additions

This leads us to consider a second method for the production of alloy grey cast iron to meet the Grade 3 specification, which is the use of base compositions with medium total carbon contents in the region of 2.9 to 3.2 per cent. with or without the aid of late silicon additions. As far as cupola practice is concerned, particularly for foundries which are lacking in technical and metallurgical control, it is easier to use a cast iron of this type with nickel and/or copper additions coupled with small molybdenum additions of the order of 0.3 to 0.5 per cent. molybdenum. These cast irons are easier to handle in the foundry and, on account of the higher total carbon content permissible, have better liquid shrinkage characteristics compared with the lower total carbon compositions. Where cupola melting is the only process available, they can be made with only small, or even without, additions of mild steel scrap, provided the greater portion of the base charge consists of so-called refined iron or low-phosphorus medium-carbon types of pig-iron. The lower carbon irons, of course, require the use of comparatively high percentages of steel scrap when they are made by cupola melting. It is not the intention in this brief survey to deal with low-carbon irons produced in rotary furnaces, electric furnaces, etc., where, of course, it is easy to obtain low-carbon compositions even when using quantities of medium-carbon and high-carbon material in the case charge.

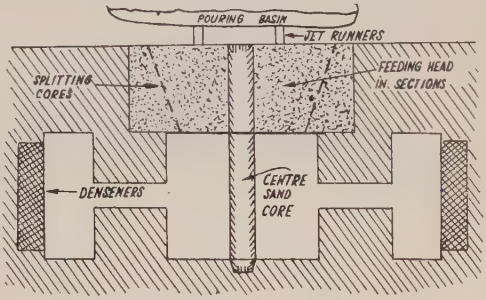

FIG. 14.—TYPICAL COUPLING.

The foundry technique required for producing comparatively complicated castings of divergent sectional thickness in these alloy cast irons of medium carbon content, differs very little from that associated in the past with so-called cylinder irons. Since, in order to maintain high strength, the phosphorus content will be comparatively low, seldom reaching a figure above 0.4 per cent., casting difficulties usually associated with high phosphorus contents, particularly in heavy section castings, do not arise.

Of much more interest to progressive foundrymen at the present time is the production of really high-strength grey cast iron possessing mechanical properties in excess of the minima called for in B.S.S. 786, Grade 4. As is well known, this specification calls for a minimum tensile strength of 25 tons per sq. in. on test-bars cast 0.875 in. dia. In order to meet this specification satisfactorily, a certain plus margin is necessary, which means that average tensile strengths in the routine production of castings to meet this specification must be about 27 tons per sq. in. In point of fact, a considerable amount of cupola melted cast iron is being made to-day with a minimum tensile strength of approximately 30 tons per sq. in. in the as-cast condition, and figures of 35 tons and over are not uncommon.

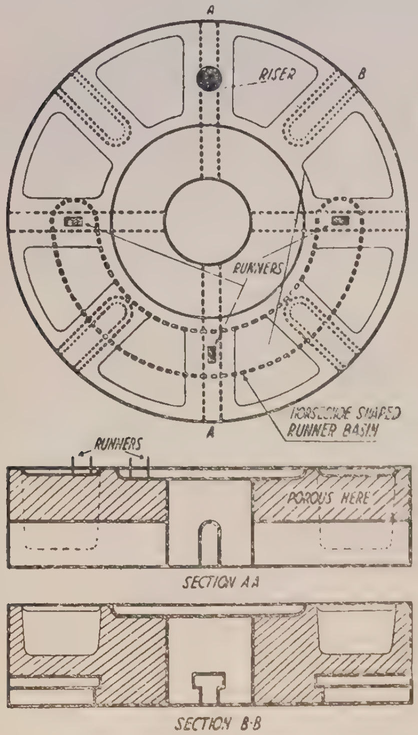

FIG. 15.—CHUCK CASTING, PLAN SHOWING RECOMMENDED METHOD, AND SECTION METHOD GIVING TROUBLE.

Acicular Structures

It is difficult to obtain cast irons with a tensile strength much over 25 to 28 tons per sq. in., in the as-cast condition, when pearlitic structures only are employed. A great deal of attention has been given lately, particularly in the technical Press, to nickel-molybdenum cast irons usually with a molybdenum content of over 0.5 per cent., where the production of a so-called acicular structure is utilised to produce high mechanical properties, including high tensile strength, transverse strength and toughness. In this connection, reference might again be usefully made to the recent Paper by Flinn and Reese, where it is demonstrated that the new high-strength acicular structures may be produced and controlled to give strengths much in excess of those associated with pearlitic cast irons. In this Paper tensile strengths up to approximately 47 tons per sq. in. are quoted.

A very important series of nickel-molybdenum cast irons has recently been developed, usually containing molybdenum in amounts varying between 0.5 and 1.5 per cent., and with nickel contents varying between 1 and 5 per cent., the nickel content being varied according to the cooling rate of the casting, the smaller the sectional thickness or mass of the casting, the lower the nickel content, all other things being equal. These cast irons, which, as already indicated, are characterised by high tensile strength and great toughness, owe their properties entirely to the structure of their matrix, always provided, of course, that flake graphite in random form is present to the exclusion of eutectic graphite. Within the range of composition given above, when correctly adjusted to the cooling rate of the casting, austenite does not transform to pearlite. Instead, at temperatures very much lower than the normal change point intermediate decomposition products are formed, and these consist largely of free ferrite needles, together with residual austenite high in carbon.

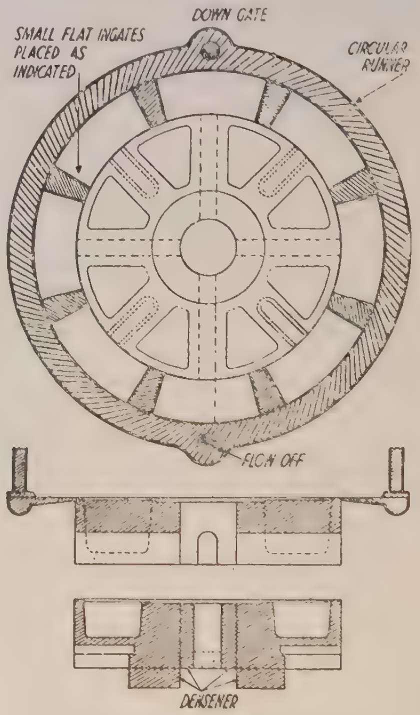

FIG. 16.—AN ALTERNATIVE METHOD OF RUNNING CHUCK CASTINGS.

Studies of a number of such nickel-molybdenum cast irons have clearly established the fact that this type of acicular structure consists of a series of austenitic decomposition products which form below the pearlitic temperature range by the precipitation of free ferrite and diffusion of carbon into the surrounding austenite. Provided the composition is suitable, a subsequent low-temperature annealing treatment, usually in the neighbourhood of 320 deg. C., will completely change the residual austenite into a wholly acicular structure. This tends to increase the tensile strength, with but a slight reduction in toughness or resistance to impact as measured by single-blow impact tests. In other words, in these acicular structured nickel-molybdenum cast irons maximum toughness is obtained in the as-cast condition if a proportion of free austenite remains, whereas maximum tensile strength with only a moderate reduction in toughness is obtained after low-temperature heat-treatment, when the residual austenite is completely converted into the needle-like structure.

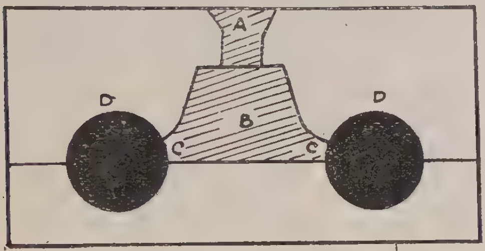

FIG. 17.—USE OF SHRINKBOB FOR SOLID BALL CASTINGS. SPRUE A DELIVERS METAL INTO ENLARGED RUNNER B. THIS FEEDS THE CASTINGS THROUGH THE MODIFIED INGATES C.

Figs. 2 and 3 show typical structures of cast iron of this type. The micrographs are taken from some actual crankshaft castings for small compressors, with a sectional thickness of $1\frac{3}{8}$ in. dia. at the point where the test-pieces have been obtained. The tensile strength of this particular sample was 34.6 tons per sq. in., and after low-temperature treatment the tensile strength was 38.2 tons per sq. in. The composition was as follows:—Total carbon, 2.89; silicon, 2.28; manganese, 0.97; sulphur, 0.13; phosphorus, 0.097; nickel, 2.30; and molybdenum, 1.25 per cent.

Future Field for Iron Castings

The above details are given merely as a very rough guide, and as typical examples of what may be achieved from cupola melted iron. It will be noted that the phosphorus content is very low. This is important, because phosphorus in excess of 0.20 per cent. tends to favour the formation of pearlite with a sudden decrease in mechanical properties for any given alloy and carbon content. The same type of composition, of course, may be applied to the special process irons which are covered by British Patents. It is felt that these alloy cast irons of medium carbon content will eventually prove very acceptable to engineers, who require high strength, tough materials which have the peculiar properties and characteristics associated with graphitic cast iron.

In fact, if one may dare to put forward a mild prophecy, one can visualise a time when the intermediate strength grey cast irons might cease to be used except for limited and special fields of application. The industry would then be left with the straight phosphoric cast irons of low strength, which will, of course, always cover a vast proportion of grey-iron requirements and the really high-strength cast irons comparable in tensile strength with steel castings and forgings, but also possessing the special characteristics of true cast iron. For example, they will still possess the inherent lubricating and wear-resisting properties of all types of graphitic cast iron, will have high capacity for absorbing vibrations, etc., and will also possess a high order of resistance to notch sensitivity.

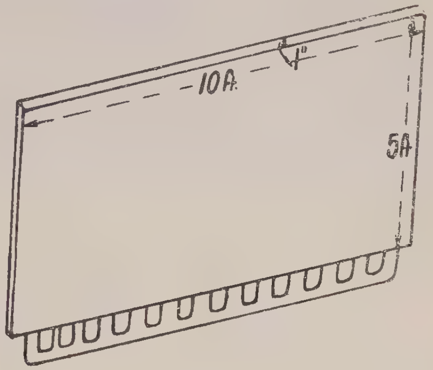

FIG. 18.—DIAGRAM SHOWING CONVENTIONAL FORM OF RUNNER FOR LARGE FLAT PLATE.

Under a state of affairs thus visualised, the medium-strength alloy and non-alloy cast irons would still find a useful field on account of their special properties, such as high wear resistance, etc. For example, the grey martensitic and white martensitic cast irons will continue to be used more and more extensively. Low alloy additions coupled with moderate strength base compositions will also find employment for promoting pressure tightness and for heat resistance under suitable conditions, etc. Dictates of initial cost will also influence any such change-over and tend towards the retention of medium-strength cast iron.

When considering all this, it must be remembered that the highest strength nickel-molybdenum irons are true cast irons, and therefore are non-ductile materials, although possessing very much superior shock-resisting qualities compared with ordinary phosphoric cast irons. Another point in favour of the nickel-molybdenum cast irons of acicular structure is that moderately high strength can be obtained with very good castability, since the total carbon content need not fall much under 3.0 per cent.

Pressure-Tight Castings

It was mentioned earlier that in the production of high-strength cast iron great attention must be paid to obtaining completely sound castings free from all traces of liquid shrinkage porosity. This is of the greatest importance when dealing with cast irons of this class on account of the types of service to which such castings are usually put. It is true that in the production of pressure-tight castings from weaker grades of non-alloy cast iron, freedom from liquid shrinkage defects is also important, but the common bedplate, the common flywheel, etc., made in various grades of iron, having tensile strengths falling between perhaps 11 and 18 tons per sq. in., can often carry under their skin considerable areas of weak structure without impairing their efficient use in service. This is not the case in regard to castings which have to be pressure tight, nor is it the case with castings which must have uniform strength throughout their mass.

No doubt many founders, particularly in Scotland, are finding considerable difficulty to-day in obtaining sound castings in medium-strength cast iron when producing designs which they have made successfully for many years. This can in very great measure be accounted for by higher phosphorus contents of the raw materials which they are using, another element which also tends to increase susceptibility to internal liquid shrinkage defects in heavier section castings. Therefore, it may not be amiss to deal briefly with foundry technique, with particular reference to the progressive solidification of castings and the provision of adequate feeding metal where the design of casting is such as to make liquid feeding difficult or where the characteristics of the metal, either on account of high phosphorus content or low total carbon content, are such that the difference in volume from the liquid to the solid state is greater than normal.

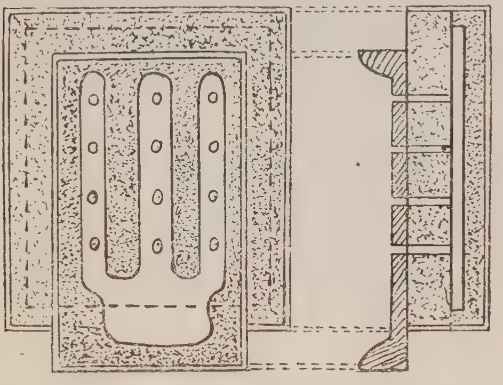

FIG. 19.—SUGGESTED METHOD TO AVOID DISTORTION.

It is, of course, well known that cast iron, compared with other metals, has comparatively low liquid shrinkage characteristics. The actual amount of liquid shrinkage will depend very largely on the carbon content, or rather depend on the amount and size of the graphite particles. The amount of actual liquid shrinkage, that is, as already stated, the difference in volume between the solid and the liquid from which it is formed, will probably vary between approximately 1 per cent. for high-carbon hematite type cast irons, up to 3 per cent. for medium low carbon cast irons, and considerably more for cast irons with a total carbon content of 2.5 per cent. and under. If, however, a grey-iron casting, whether in high-strength or low-strength material, was of such a design that solidification could take place progressively from the bottom of the casting upwards, or, in exceptional cases, could take place simultaneously throughout its whole mass, then it would be a very simple matter to counteract this difference in volume between the solid and the liquid state. Unfortunately, this is not the case.

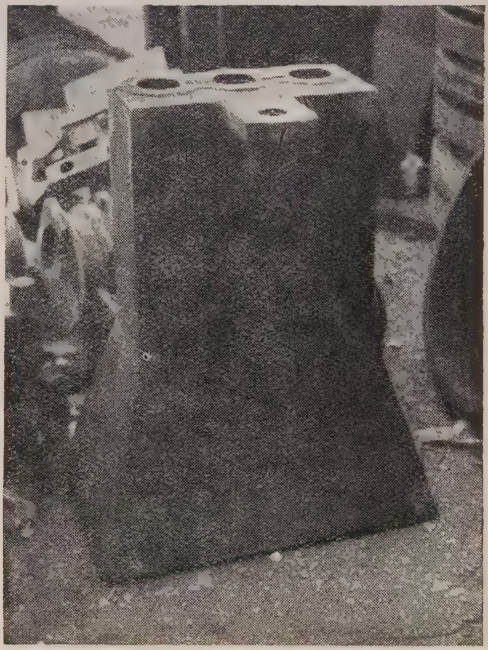

FIG. 20.—CASTING OF A CO_2-PUMP BODY, SHOWING LARGE FEEDING HEAD.

The question of internal inspection of castings by radiology was briefly mentioned at the beginning of this talk, and in all seriousness it is suggested that founders specialising in the production of high-strength iron castings should prepare themselves for this type of inspection being applied to their castings in the future.

Another interesting sidelight on the degree of perfection of castings has come to light recently when applying the process known as "Induction Hardening" to cylinder liner bores. A recent article* by Fredk. P. Peters and Edwin

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* "Metals and Alloys," June, 1941.

F. Cone, dealing with this process, contains the following statement:—"An interesting side feature of the process for the induction hardening of cast-iron liners is its simultaneous use as an additional inspection where the part being treated is porous or cracked. An abnormality of the heating occurs within the piece and manifests itself by melting the surface or wall adjoining the defect. In the case of porosity, marked signs of overheating can be discerned. Consequently defective stock can be easily identified. In fact, defects otherwise discernible only by Magnafluxing or microscopic inspection are readily revealed in this way."

Cylinder Liners

The point made above is of particular interest to the speaker, because probably there has been more controversy ranged around methods of casting cylinder liner castings of all types in the foundry industry than with any other variety of component. For example, very often a foundry strikes trouble with small-bore, thin-walled liners, which are sand cast, after obtaining reasonably satisfactory commercial results over a long period previously, and cannot understand why this has occurred. A personal answer to that is, unless the castings are of an extremely thin-walled nature, some microscopic liquid shrinkage defect will almost invariably be present, but it may not be revealed by machining, or, if it is, the defect is so minute that it is overlooked by normal methods of inspection. Slight variations in composition and cooling rate, etc., will tend to increase or decrease the magnitude of this defect, and consequently it will be sufficiently great in some batches of castings to be readily visible and cause rejections. Directly opposed to this there are the manufacturers of Diesel liners for main propulsion marine engines, who cast liners with very little difficulty up to probably 5 tons in weight and 30 to 40 in. in diameter, but probably it will be found that almost invariably their practice is to use suitably designed feeding heads to provide liquid metal to feed the remainder of the castings during the process of solidification. To continue on these lines a little further, occasionally one encounters a particular type of Diesel engine liner, the design of which is such that it may carry a flange at some intermediate point between the top and the bottom of the casting. It is well known in Diesel engine foundries that this is a very difficult type of liner to produce, and that some artificial method, such as the use of denseners, has to be adopted to prevent defects due to liquid shrinkage porosity at that point.

It may, of course, be argued, and it is postulated by some authorities that these liquid shrinkage troubles are only characteristic of high strength and special cast irons. This unfortunately is very far from the truth, because a great many of the castings such as automobile cylinder blocks and cylinder heads, Diesel cylinder liners and forging dies, to mention only a few examples, in the form and design often called for could not possibly be produced free from liquid shrinkage defects in high phosphorus irons without resort to similar and even more drastic precautions. It is well known that high carbon irons, usually associated with relatively high silicon contents, possess greater castability than high strength irons, but if they were used for the production of many types of lumpy heavy section castings, the resulting material would be so open-grained as to be useless.

Therefore it will be seen that in order to get close-grained, strong material it is necessary to have resort to cast irons whose castability and liquid shrinkage characteristics are not quite so good. On the other hand, of course, as far as high strength cast irons are concerned, they are usually of low phosphorus content, and this to some extent offsets the difference.

Runners and Feeding

When tackling the production of any particular design of casting in high strength cast iron, before the pattern or moulding tackle is made for the job, the foundryman should invariably give ample consideration to the attainment of complete solidity and soundness in the finished article. All possible means should be taken as far as distribution, type and shape of runners are concerned to ensure progressive solidification. In general this is usually accomplished by making certain that the following conditions are fulfilled as far as possible:—

(1) The difference in rate of cooling between thin and thick sections should be equalised as much as possible. This is usually achieved by superheating the portions of the mould which form the thin sections and so directing the flow of metal that colder metal fills the heavier sections.

(2) Other conditions, such as importance or location of machined faces permitting, arrangements should be made to cast the heavier masses towards the top and, by a combination of design of runners and use of feeding heads, ensure progressive solidification from the bottom upwards.

(3) Where external feeders cannot be used equalisation of cooling should be attempted by the very careful use of external denseners placed either in the core or mould body.

(4) Rod or puddle feeding must on no account be attempted in the production of castings, where complete uniformity of properties is required throughout the mass.

In this connection, of course, the term "uniformity" is used in a comparative sense since there will be some difference in properties between thin sections and heavy sections. It should be remembered, however, that with the compositions and special processes now available for the production of high strength cast iron, this gradient or decrease in tensile strength as the sectional thickness increases and consequently the cooling time is prolonged, is very much less than is the case in the weaker, higher carbon, non-alloy cast irons.

In order to illustrate this a few typical simple examples are given. It must be borne in mind that these are of a very elementary nature, and appertain to simple shapes of castings. The same principles, however, can be applied to the largest casting and the most complicated casting. Dealing with particular portions of the castings on the lines indicated, *i.e.*, in the case of heavy marine engine cylinders, Diesel engine castings, air compressor castings, hydraulic castings and even machine tool castings, it is often advisable to use a combination of the principles indicated. It is well known, of course, to most foundrymen that simple, lumpy castings, if they have to be completely sound throughout their whole mass, are very often more difficult to produce than large castings like bedplates, etc., weighing many tons. The larger the casting, other things being equal, the slower the rate of cooling, and consequently there is less tendency for sharp differences in cooling rates in a big casting, even provided it shows considerable diversity of sectional thickness. Usually heavy masses in large castings, even when adjoining comparatively light sections, can be dealt with individually.

Self-Feeding Heads

Examples of self-feeding heads will be dealt with first, and Fig. 4 shows a typical plain liner casting. These castings are of the simplest possible design, and are in fact small plain sleeves, and of course are found in foundry practice in all sizes from very small thin-walled castings up to very heavy plain hydraulic liners, etc. The illustration and all those to follow naturally apply only to sand castings. Similar castings are made very extensively and in very large numbers by centrifugal casting methods in spun metal moulds. The essentials of this latter method, namely rapid cooling coupled with centrifugal force, eliminate the possibility of all liquid shrinkage defects.

Fig. 4 shows at D a method which is often erroneously employed. Even in comparatively thin walled liners a feeding head composed merely of an extension of the casting is rarely satisfactory, unless, of course, it is of excessive height. Such a casting irrespective of the method of pouring tends to solidify in the form of a shell, and consequently the last portion to solidify may be at some point lower than the top of the casting proper. To avoid this it is common practice to adopt either of the other three designs of feeding head A, B and C. Each of these has in common the characteristic of possessing a greater bulk of metal, which will remain liquid and feed the casting after the casting proper has solidified. Personally, type C is preferred because it is easy to mould, easy to handle, and has advantages for manipulating the casting in the machine shop. Type A is equally good, but where castings have to be chucked from the head end this completely tapered form presents disadvantages. Type B is rarely employed unless it is desirable or necessary to economise in the size of box required to produce the casting, or some such consideration.

In all cases plain liners of this type should be entirely top run, usually with jet runners round the top of the feeding head. This makes doubly sure that the feeding head is the last portion to solidify, and promotes progressive solidification from the bottom upwards. Even in very simple castings of this kind it is bad practice to run them from the bottom, because this upsets progressive solidification, superheating the bottom of the mould and tending towards promoting initial solidification somewhere towards the middle of the casting.

Progressive Solidification

Fig. 5 shows a similar type of liner casting carrying a top flange. This illustration is self-explanatory, but it should be noted that with all liners of this type the thickness section of metal and therefore the portion likely to be the last to solidify is on the diagonal between the top inside of the bore and the bottom outside of the flange as indicated at X. The section of the feeding head at its base should be at least greater than the dimension X.

Fig. 6 represents diagrammatically a type of casting which is sometimes encountered in the form of gland sleeves, liner castings, elongated bushes, etc., where a heavy flange is situated remote from either end of the casting. In this case, in order to promote uniform density of structure and progressive solidification, it is usual practice to use comparatively heavy external denseners. In some cases it is possible, where the heavy flange is near one end of the casting to add an extra machining allowance and adopt the normal type of flared feeding head. This, of course, is to be preferred where it can be used since denseners may then be dispensed with.

These first three simple illustrations of liners and sleeves show methods which, of course, may also be adapted to similar portions of large and complicated castings, for example locomotive cylinders, gas compressor bodies, etc.

Forging Die Sleeves

Fig. 7 shows a typical forging die sleeve as used in the manufacture of pot-like forgings from square steel billets. Usually the wall thickness will be 2 in. and over. In fact, for some dies it may be anything up to 8 in. at the heaviest section. In the case of castings of this type working under severe conditions, as takes place in the hot piercing of steel billets, it is not sufficient to have superficial soundness in the castings after all-over machining operations have taken place. If any trace of undisclosed liquid shrinkage porosity is present somewhere in the wall of such a casting then it will fail prematurely by gradual collapse of the inner working surface. A suitable and reliable type of feeding head, combined with top running, is shown in this illustration. It is just possible, of course, in this case that there will be sufficient bulk of metal available if the casting is extended, taking advantage of the taper present, but to make certain it is worth the extra trouble to have a self-feeding head of the correct type. After all, the cost of parting off such a head is exactly the same whether it is flared as indicated or whether it is parallel.

Fig. 8 shows an incorrect method of making such castings. This may seem rather ridiculous and not likely to be encountered in actual practice, but an assurance is given that this is not the case. When a tapered bore sleeve or bush of this type is cast with the heavy section downwards, particularly when it is poured by bottom runners, liquid shrinkage defects may be depressed to within a short distance of the bottom, since the last part of the casting to solidify is located there.

Headstock Spindles

Figs. 9 and 10 show two methods of producing a high-duty cast iron lathe headstock spindle. Here, of course, is another case where very great care has to be taken to avoid any undisclosed porosity. The alternative material for such spindles is usually steel forgings, in which there is little risk of internal defects. Cast iron is very popular for this application on account of its rigidity, etc. Here again one has to cater by means of a feeding head to ensure freedom from liquid shrinkage porosity, but one must also consider a foundry technique which will prevent buckling of the core at the narrow neck. Fig. 9 shows the ideal method, but some foundries might encounter difficulty with core buckling, and as an expedient might resort to the method shown in Fig. 10.

Fig. 11 shows a similar type of casting where it has been deemed inadvisable to core out the middle portion which has a finished internal diameter of 1½ in. Some foundrymen may claim that it is quite easy to core out this job throughout its whole length, but when one considers the thickness of the metal involved it then presents considerable difficulty.

Fig. 12 shows a type of massive hot heading die, also for steel forging operations. The castings for this application are usually encountered in various sizes, and consist of what might be termed a large lump of cast iron in diameters up to probably 24 in. The working part of the die-face proper is only a very small portion of the casting, yet complete soundness in the whole mass of the casting is absolutely essential, even in high-duty iron if it is to stand up to the required conditions. This method shows the simplest and most foolproof method, but it has disadvantages in the cost entailed in parting off a large feeding head. Fig. 13 shows an alternative method of casting using heavy denseners.

Lumpy Castings

Very often one encounters difficulty with simple lumpy castings, such as couplings, which have to be made in cast iron of high tensile strength, and have to be completely sound throughout their whole mass. In extreme cases it may be necessary to adopt the feeding head method, but very often there is great difficulty in parting off such feeders. Unfortunately in cast iron they cannot be removed by oxy-acetylene cutting as is the case in steel castings, where the adoption of similar heads is being practised.

Fig. 14 shows a method which can be used to overcome this. The feeding head is split into four or more segments by means of splitting cores usually about ¾ or 1 in. thick. They do not interfere to any great extent with the feeding properties of the head, and yet they allow of the segments of the feeder being removed by hammer, heavy ball or similar methods.

Machine Tool Chuck Castings

Figs. 15 and 16 show alternative methods for running typical machine tool chuck castings in high-duty cast iron. Wherever possible all circular castings, which are required not only

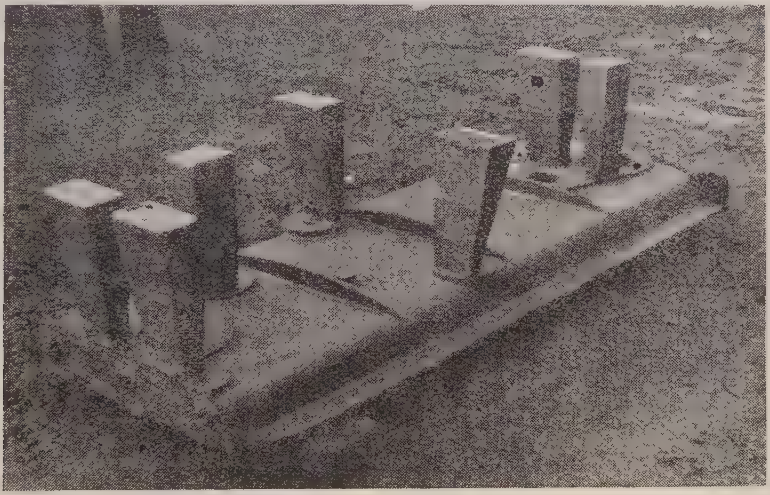

FIG. 21.—CONDENSER END HEADER SHOWING HEAVY FEEDERS.

in high strength cast iron but which have to be completely free from porosity, should never be run from one individual point. Methods of running should be studied very carefully to permit as equal distribution of the metal in the mould as possible, always keeping in mind the principle of superheating the thin portions and speeding up the rate of cooling of the heavier portions. Very often it is necessary, in order to cool heavy portions more rapidly, to have recourse to denseners, but these should only be used where the design or other circumstances make it impossible to use self-feeding heads.

Shrink bobs are more often associated with the production of malleable iron rather than grey cast iron, but they can be and are used effectively to promote soundness in small lumpy castings, particularly where these are being machine moulded from a number of patterns on a plate.

Grinding Mill Balls

Fig. 17 shows a very simple example used in the manufacture of ball castings for grinding mills, which are usually made either in ordinary white iron or in martensitic Ni-Hard white iron. This material shows considerable liquid shrinkage, and if grinding balls are to be efficient in service they must be completely sound throughout their whole mass. Obviously spherical castings of this type tend to solidify from the skin inwards, and eventually leave a hollow cavity in the centre. Also in high-duty and other types of grey cast iron the same principle can be used to advantage for small, solid cylindrical castings, which must be completely non-porous in the centre to allow for deep machining and drilling operations without showing signs of even the most minute porosity.

Large Flat Plate Castings

Fig. 18 shows the typical method usually adopted in the production of large flat plate castings. The illustration is meant to give some idea of a plate 10 ft. by 5 ft. by 1 in. thick, the top, of course, being covered. Running from one side as illustrated tends to cause warping and buckling, as well as lack of uniformity and irregular hardness throughout different parts of the plate, by reason of the fact that metal reaching the points most remote from the runner cool at a different rate to those in close proximity to the runner.

Fig. 19 shows diagrammatically a much more desirable method of running these plates, with small drop ingates distributed over the top surface in such a way as to promote progressive solidification. The illustration, of course, is only diagrammatic, and in actual practice the openings of the downgates from the runner basin would be plugged or covered with dross plates to keep a sufficient head of metal and also to prevent slag and dross from entering the gates.

The same principle can be applied to large bedplates, lathe beds, drillings and milling machine tables, etc. This method of running from the top, either from a central point or at equally distributed points over the top area, will not only give greater freedom from liquid shrinkage porosity in such castings, but will also notably reduce the camber by eliminating unequal cooling rates, with consequent reduction of residual internal stresses, etc.

Fig. 20 illustrates a carbon-dioxide pump body casting required to be pressure tight under high liquid and gaseous pressures. At first sight the feeding head seems enormous and out of all proportion to the remainder of the casting. The material used for this casting is of the 30 tons per sq. in. tensile strength nickel-molybdenum type of cast iron. The only alternative material available for these castings would be an almost solid steel forging, in which cast iron liners would have to be inserted in the bores. With high strength cast iron the inherent properties of graphitic material are at once available, and the strength of the body is quite adequate for the duty entailed. The extra cost of removing the large head is more than amply compensated for by the fact that it is possible to cast the working parts of the component reasonably near to size, thus reducing the cost of machining operations on the casting proper.

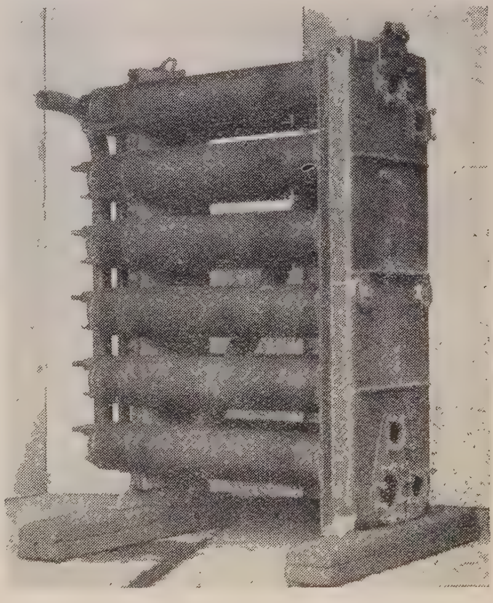
FIG. 22.—NI-RESIST CONDENSER HEADERS.

The above examples are put forward merely with a view to giving general indications and tendencies and, of course, are extremely elementary and simple in themselves. However, as already emphasised, these methods can be applied to large and complicated castings either individually or in various combinations.

Feeding Special Irons

Space does not allow of discussing running and feeding methods as adopted in the more specialised types of alloy cast iron. Perhaps it will be enough to say that, as far as intermediate alloy irons are concerned, for example grey martensitic irons and white martensitic irons, no special precautions are necessary, and methods found suitable for ordinary grey iron castings in the case of the former and for ordinary grey iron castings in the case of the latter can be successfully adopted. No attempt will be made to deal with the high silicon irons, which require a special technique of their own due to their peculiar properties. A few indications might, however, be profitably given concerning foundry technique for the production of austenitic cast iron.

Taking Ni-Resist containing approximately 14 per cent. nickel, 7 per cent. copper, and 2 per cent. chromium as typical of these irons, the main points requiring attention from the moulding, coremaking, and running aspects are as follow: In general terms Ni-Resist austenitic cast iron should be poured at higher temperatures and more rapidly than is the case with grey iron, because it sets more quickly. Efforts should always be made to arrange the layout of the work in foundries handling Ni-Resist in such a way that the moulds are poured as soon as possible after tapping of the metal is completed. Green- or dry-sand moulds may be used in exactly the same way as for other types of special cast iron, the choice being left to individual producers, bearing in mind the size and mass of the castings.

The pattern shrinkage allowed for Ni-Resist is greater than that of ordinary cast iron, the amount usually necessary being $\frac{5}{32}$ to $\frac{3}{16}$ in. per foot. Because of the linear shrinkage characteristics of Ni-Resist, castings containing large or complicated cores should be constructed in such a way as to be easily crushable. In many cases it may be necessary to relieve or dig out such cores or parts of cores in order to relieve stresses and avoid cracking. This is achieved in the usual way, and care should be taken with the larger sized cores that core irons and similar reinforcements are kept sufficiently remote from the skin of the core that they will not impede contraction.

The fluidity of Ni-Resist is good and the metal holds its life well in the ladle, but its comparatively low total carbon content may make it set rapidly in the mould. Therefore the dimensions of the ingates should be large, so that rapid pouring can be accomplished. This should be achieved rather by the use of thin, wide gates, than attempting to get the increased area into individual square or circular section runners. By the use of thin, wide gates, the advantages of pouring rapidly can be obtained without risking the possibility of liquid shrinkage defects or, alternatively, openness of grain which is often found where heavy section gates join the castings.

The liquid shrinkage characteristics of Ni-Resist approach those of steel, and, therefore, in order to obtain castings free from liquid shrinkage porosity defects, it is necessary to use steel moulding type of feeders. High ferrostatic head pressure will also assist in densifying heavy sections. Denseners may also be used to equalise cooling rates, exactly as is the case with grey-iron castings. Even with the use of denseners, however, in most cases it is desirable to resort to heavy feeders.

Use of Chaplets and Studs

One other word of warning concerns the use of chaplets or studs for core anchorage. Where it is necessary to use such core anchorage devices, the chaplets should be made of Monel metal, so that uniformity of composition of the casting may be maintained. However, as in the case of high-duty and high-strength iron castings, the use of chaplets should be strictly limited to cases where all other alternative methods of core anchorage will not give the desired result.

The cleaning and fettling of Ni-Resist castings does not call for any special comment, except that the iron is not hardened by being exposed to air after solidification. Therefore, the castings may be shaken out at an early stage after they have become set. Runners and risers can be removed by the same practice as is used in the fettling of ordinary grey-iron castings. Cleaning in tumbling barrels should, however, be avoided, since such a procedure may tend to cause hardness on the skin due to work-hardening effects, and thus introduce machining difficulties.

The feeding heads for such castings, as already explained, should be on the lines usually recommended for steel castings and call for no special comment, except that they must be sufficiently large to provide ample liquid feeding metal for the area of the casting which they take care of.

Fig. 21 shows a rather extreme example of the use of heavy feeders on a condenser end header. The casting has to be pressure tight and incorporates a horizontal baffle of metal through the casting. Fig. 22 shows the same casting after machining and erection in the cooling unit of which it is a component.

Cupola-Melted High-Duty Cast Irons*

By W. W. BRAIDWOOD (Associate Member)

The advent in 1938 of B.S. Specification No. 786 heralded a new era in iron-foundry practice. From that year, no progressive firm could afford to lack the means of producing castings to satisfy the most exacting of the new requirements. Then, as now, two well-established patented processes were available to interested concerns. By the utilisation of either, it is claimed, high strength irons may readily be produced from the cupola. Details of these protected processes are, naturally, disclosed only to licensees, but it may safely be stated that they have in common two essential features:—(1) Incorporation in the cupola charge of appreciable proportions of steel scrap, and (2) spout or ladle addition of graphitising agents.

In the foundry with which the writer is connected, it was decided to proceed with the development rather than the adoption, of a satisfactory technique. Good quality cast irons, with tensile strengths of the order of 18 tons per sq. in., were, and still are, constantly being produced in considerable volume and by very economical means, the cupola charges consisting essentially of chill-cast, 3 per cent. silicon pig-iron and steel scrap. It seemed logical to expect that modification of this procedure, with the aim of eventual elimination of the high-carbon, graphite-bearing constituents of the cupola charge, should result in improvement in the physical properties of the irons produced. In short, it was hoped ultimately to employ all-steel charges, supplying the necessary silicon and manganese by ferro-alloy rather than pig-iron additions.

Cupola charges of this type were expected to yield final carbon contents within the range of 2.5 to 3.0 per cent. This feature of composition would provide satisfactorily low percentages of graphitic carbon in the resultant grey iron structures, would permit the use for castings of normal section of silicon contents in excess of 2 per cent., and would, as reported by MacDougall,[1] render variation in silicon content above that figure less able acutely to influence the structure and properties of the irons produced.

Summary of Experimental Results

The initial experimental melts were carried out on the lines indicated, and the results were immediately encouraging, tensile strengths in excess of 20 tons per sq. in. being obtained on the 1.2 in. dia. bar. A careful record was kept of all circumstances, and results and much useful information accrued. While it is not proposed to describe this exploratory work in detail, the main findings may be quoted as follows:—

(1) The procedure was successful in its object of producing cast irons satisfying the highest requirements of B.S. Specification No. 786.

(2) The material cost of high strength iron produced in the manner outlined was actually lower than that of ordinary cast iron produced from charges of the orthodox type.

(3) Conventional ideas with regard to coke: metal ratios do not apply to the melting of high-steel charges. It must constantly be remembered that a really considerable proportion of the total weight of coke charged is utilised, not as fuel, but as the provider of carbon absorbed by the melt.

(4) The physical condition of the scrap steel used in such cupola charges is a most potent factor. Wherever possible the scrap employed should be of standard type since variation in its form is liable to cause considerable variation in the results obtained. As the ratio of surface area to mass is decreased, that is, as the section thickness of the scrap is increased, oxidation losses on cupola melting tend to be reduced. Massive scrap, however, is unsatisfactory since it melts sluggishly, and the ideal type of steel scrap for cupola melting is probably that which is moderately heavy in section and of hollow form. The writer is fortunate in having at his disposal adequate supplies of scrap of this description, with an average surface/mass ratio of approximately 10 sq. in. per lb. Typical examples are illustrated in Fig. 1.

Test Procedure

Actual production of high-strength iron castings was then begun under carefully controlled conditions, the aim being to combine profit-making operations with informative practical research. Before commencing the report of this work it is probably advisable to provide a precise description of the test procedure so that the results soon to be quoted may be capable of absolute interpretation.

All test-bars were poured from the ladle containing the whole bulk of the tap studied, and never from metal caught at the cupola spout. All analyses, micro-examinations, and physical tests were conducted on 1.2 in. dia. bars, poured, and allowed to cool, within standard oil-sand moulds of the design illustrated in Fig. 2; and all of the results quoted relate to bars tested in the "as-cast" condition.

The bars were first broken in transverse on 18-in. centres and determinations made of transverse rupture stress and deflection; but, since the bars were unmachined at that stage, and were, therefore, never of truly circular cross-section, the figures obtained are not reproduced. It should be made clear, however, that they were consistently and considerably in excess of the requirements for High Duty Iron, Grade 3.

All other tests were carried out on specimens machined from portions of the fractured bar. The tensile test-pieces, 0.798 in. dia. on the gauge length, were provided with threaded ends which, during test, were located within self-aligning grips. Hardness was expressed as the average of three determinations in close agreement, conducted on the cross-section of the 1.2 in. dia. bar. The indentations were equally spaced around the circumference of a circle, concentric with the contour of the bar, but of half its diameter, and use was made of the standard Brinell machine, with the 10-mm. ball and 3,000-kg. load.

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* This Paper was also presented to the Falkirk Section.

Single-blow impact tests were conducted in accordance with the recommendations of the British Cast Iron Research Association, on unnotched bars, 0.798 in. dia., broken in a standard 120 ft.-lb. Izod machine fitted with a modified vice. This is designed to hold the round specimen and to give a striking height of 1.3 in. (The gaps, which will be observed to occur under the heading "Impact," are due to the fact that this test procedure was established only when the investigation was well advanced, and several of the retained specimens were found to have an insufficient length of unused bar remaining.)

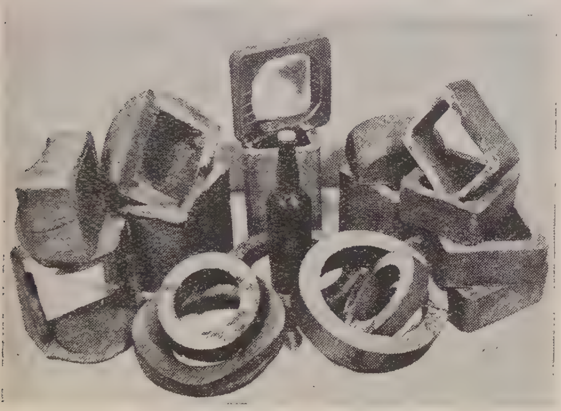

FIG. 1.—RECOMMENDED TYPE OF STEEL SCRAP.

In every case, the specimen submitted for microscopical examination, and the drillings supplied for analysis were obtained from positions approximately midway along the length of the bar. All of the reported determinations were made by a very competent staff under purely research conditions, and duplicate tests were conducted, wherever confirmation seemed desirable.

Recording Details

Full details of all conditions and results were carefully tabulated in a form providing ease of reference and comparison, and the following were listed as subjects deserving of particular study:—

(1) The influence of variations in coke quantities: (*a*) The height of the charged bed; (*b*) the weight of the unit charge; and (*c*) the depth of subsequent and/or separating layers.

(2) Determination of the most efficient and economical means of making the required additions of silicon, manganese, etc.

(3) The influence upon the structure and properties of the resultant irons exerted by: (*a*) Incorporation of proportions of returned scrap in the cupola charge; (*b*) spout or ladle additions of graphitising agents; and (*c*) the presence of alloying elements, singly and in combination, and in various concentrations.

For this programme of production and practical research use was made of a 32-in. dia. cupola of orthodox design; indeed, just that type of cupola likely to be found in almost any iron-foundry. A sketch of this furnace will be presented later, and at this juncture it will be sufficient to state that it is fan-blown at a maximum pressure of 21 in. water-gauge, the air entering through a single row of four tuyeres, each of rectangular cross-section and measuring 5 in. long by 4 in. deep.

This unit is in everyday use melting low-silicon irons for the production of white-iron castings. The charges employed, which consist of hematite pig, steel scrap and returned white-iron scrap, are, fortunately, very suitable for melting in association with high-steel charges for high-duty irons.

Cupola Practice

For the initial melts the bed was made up to a level 48 in. above the tuyeres, and very satisfactory results were obtained. Subsequently, this height was reduced in stages to 36 in. with no measurable alteration in the temperature, composition or properties of the tapped metal. Further lowering of the bed height, however, was found to be accompanied by some reduction in temperature. The height of the charged coke bed was thereupon standardised at 36 in., and this is carefully maintained in all instances by dip rod control.

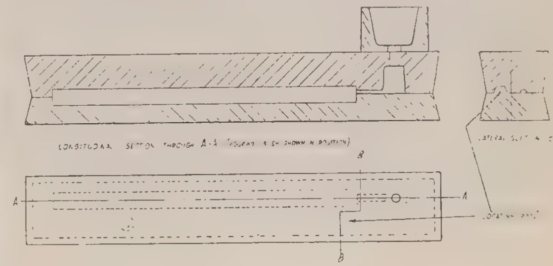

FIG. 2.—OIL-SAND MOULD FOR 1.2-IN. DIA. TEST-BAR.

The maintenance of normal conditions throughout a lengthy melt of high-steel charges can be a matter of some difficulty. Simultaneously with the progress of such melts there tends to occur a progressive lowering of the carbon, silicon, and manganese contents of the tap. The proneness of the ferro-alloys, etc., to melt prior to the accompanying steel scrap contributes to, but is not the chief cause of this condition, and it is undeniably the case that, unless preventive measures are adopted, melting conditions, with charges of this type, become progressively more oxidising as the melt proceeds.

Field,[2] Hudson,[3] Russell[4] and Mackenzie[5] have each demonstrated convincingly that, in the cupola, steel scrap is not carburised to any appreciable extent until it is actually molten. That is to say, such scrap melts as steel and not as highly-carburised metal of much lower melting point. That being so, and since the melting point temperatures of mild steel and of normal cast iron are approximately 1,500 and 1,150 deg. C., respectively, steel scrap in the cupola must melt at a level considerably nearer to the zone of maximum temperature than does cast iron. Therefore, when steel is melted, a relatively shallow bed of incandescent coke is available for superheating. Moreover, since carburisation takes place almost entirely after the steel has become molten, the carbon absorbed, which is of considerable amount, is derived wholly from that shallow layer of burning coke. This, in turn, causes further reduction in the actual bed height, and the observed increase in oxidation, the lowered carbon content and the eventual fall in temperature normally accompanying progress of melting of all-steel charges, become logical expectations.

An essential factor, therefore, of constancy of the conditions of melting is continued adequacy of the depth of that vital coke layer. Two alternative methods of ensuring such maintenance come readily to mind:—(1) The employment of really generous unit coke charges, and (2) the provision of extra coke, in the form of separating or "sandwich" charges, as required.

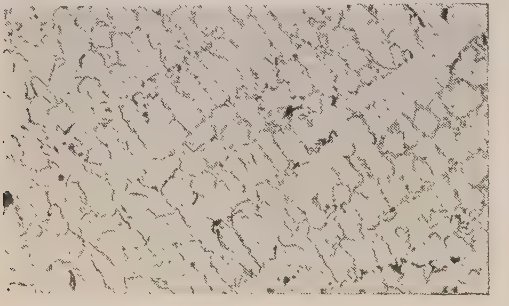

FIG. 3.—TEST-BAR FROM MELT NO. 9. PHYSICAL TEST RESULTS: HARDNESS, 264 BRINELL; TENSILE, 23.84 TONS PER SQ. IN.; IMPACT, 11 FT.-LBS. UNETCHED × 50 DIA.

Heavy Coke or Sandwich Charges?

To test the possibilities of the former method, experiments were made in the use of more and more generous unit coke charges, but, even when the "charged fuel: metals" ratio was raised to 1:6½, the observed tendency to produce progressively harder iron, though markedly reduced, was not eliminated.

Experiments subsequently made on the basis of the second alternative have shown this to be a complete success. The coke "sandwiches" are inserted at the intervals indicated as the limits of the individual taps—generally these are of 30 cwt. each—and the greater certainty of proper location of the charged alloys which their presence promotes, is an additional advantage. They therefore assist greatly in ensuring uniformity or sharp difference in the composition of successive taps, as desired. Their presence, moreover, makes possible the restriction of unit coke charges to very scanty proportions without ill effect. Full details of all the circumstances of an actual melt will be quoted later in this Paper, in order to provide concrete recommendations with regard to coke distribution.

At the outset the necessary silicon, manganese and chromium additions were made exclusively in the form of charged briquettes. These consist of ferro-alloys crushed to within certain limits of size, bonded with cement and moulded in distinctive shapes. They are undoubtedly a very convenient form of addition, and the specifications made with regard to their respective alloy contents were confirmed by analysis. It is claimed that, owing to the protective action of the binder, oxidation of the alloying material is minimised. When, however, the melting losses for silicon and manganese were found to average approximately 20 and 30 per cent. respectively, it was decided to experiment with alternative materials.

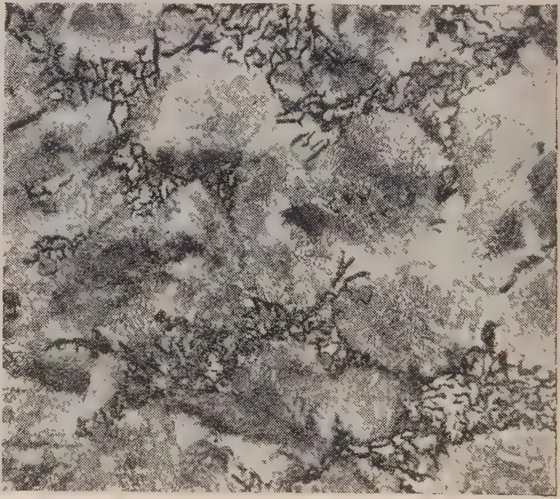

FIG. 4.—TEST-BAR FROM MELT NO. 9. ETCHED (3 PER CENT. NITAL) × 250 DIA.

Unprotected ferro-alloys were charged, and the results from the subsequent melts showed that lump ferro-silicon is actually a more efficient alloying medium than the briquetted material. The explanation may lie in the fact that the particles of ferro-silicon incorporated in the briquettes, being very much smaller than the alternative fist-sized pieces, eventually expose to oxidising influences a much greater area of surface per unit of mass. Two further materials, 15 per cent. silicon pig-iron, and lump calcium silicide, were available in small amounts and the opportunity was taken to test their possibilities. The complete list of fairly comparable test results is set out in Table I.

It is demonstrated that:—

(1) Each of the materials tested is capable of successful use in the production of high-tensile irons.

(2) From the point of view of silicon recovery, unprotected ferro-silicon is the most efficient of all. Indeed, when cost is considered, the charg-

ing of lump ferro-silicon is shown to be by far the most advantageous method of adding silicon in the cupola. (Note.—Figures of cost are quoted for purposes of comparison only, and are calculated from the market prices ruling at August 31, 1939.)

(3) Micro-examination showed the matrix of each of the specimens to consist of pearlite, resolved, in all instances, at a magnification of 250 diameters. The size and arrangement of the graphite, however, was seen to vary widely, ranging from extremely fine, interlacing deposits, distributed in a network around the grain boundaries, to relatively coarse flakes presenting no definite patterns whatsoever.

(4) This wide variation in graphite size and arrangement appears to exert no dominating influence upon the tensile strengths of the irons concerned, but resistance to impact is markedly affected. It is evident that this property is inversely proportional to regularity of the graphite pattern; that is to say, the more haphazard the distribution of the graphite flakes, the greater the resistance to impact possessed by the whole mass —all other factors being equal.

FIG. 5.—TEST-BAR FROM MELT NO. 6. UNETCHED × 50 DIA.

The last relationship may readily be traced by reference to Table I, and photo-micrographs of the structures of three of the cast irons featured therein have been chosen to illustrate the variations in graphite form occurring in irons of otherwise similar type.

Form of Graphite

The unetched structure of the bar poured from melt No. 9, at a magnification of 50 diameters, is shown in Fig. 3. The graphite is present entirely in the form of very small flakes outlining the boundaries of what were originally the crystals of austenite formed in the earlier stages of the process of solidification. Graphite of this type has been variously referred to as "supercooled," "dendritic," "abnormal," "eutectic" and "eutectiform." Not one of these terms is strictly correct, and some are actually misleading. Recently the term "grain-boundary graphite" has been introduced, and this is undoubtedly the most accurate description so far applied. Indeed, its only shortcoming is its length, which is sufficient to be cumbrous. To describe graphite of this type the present writer prefers to use the term "reticular," which is defined as:—"Having the form of network," "formed with interstices," "resembling a net," and, even at the risk of monotony, this description will be applied throughout the present Paper.

The etched structure of the same specimen at a magnification of 250 diameters is shown in Fig. 4. The matrix is seen to consist of finely divided pearlite. At this higher magnification the individual graphite flakes are seen to be present as a multitude of tiny interlacing flakes framing the grain boundaries. This particular mode of occurrence will be termed "lacy, reticular" graphite, throughout. The drastically weakening effect which such an inter-granular concentration of graphite will produce can readily be imagined, and it is no surprise to find that the presence of lacy, reticular graphite is always associated with low resistance to impact.

The structure of the test bar poured from melt No. 6 is illustrated in Figs. 5 and 6, preparation and magnification being respectively as detailed for the previous specimen. Here there is a good example of a composite graphite arrangement, two distinct and readily identifiable types being co-existent. Though the bulk of the graphite present is in the form of medium-sized random flakes, a considerable proportion is of the lacy, reticular type, and the areas involved are definitely dendritic. Again the matrix is of finely-divided pearlite, and the tensile strength is of the order of 24 tons per sq. in., but resistance to impact is now markedly improved. Figs. 7 and 8 show the micro-structure of the test bar poured from melt No. 20, preparation and magnification being exactly as previously described. In this specimen the graphite is present entirely in the form of long flakes in random dispersion. The distribution is completely haphazard, and there is no trace of reticular arrangement. As before, the matrix is pearlitic, and the tensile strength is approximately 24 tons per sq. in., but the resistance to impact is now practically twice that of the first bar. (It is noteworthy that in each instance in which calcium silicide was charged, the resultant test bar exhibited random graphite and high resistance to impact.)

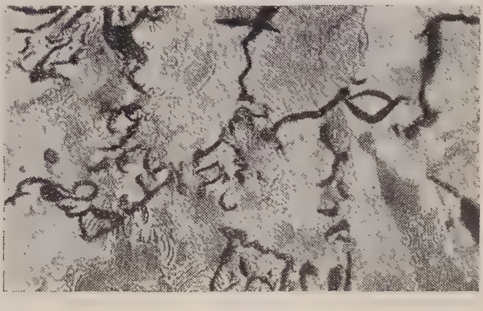

FIG. 6.—TEST-BAR FROM MELT NO. 6. PHYSICAL TEST RESULTS: HARDNESS, 241 BRINELL; TENSILE STRENGTH, 24.20 TONS PER SQ. IN.; IMPACT, 14 FT.-LBS. ETCHED (3 PER CENT. NITAL) × 250 DIA.

Reticular Graphite and Impact Resistance

Careful study of Table I will repay the interested investigator. It will be observed that the presence of reticular graphite is always associated with lowered resistance to impact, though tensile strength does not appear to be appreciably influenced. It is desired to emphasise the latter fact, and the case of melt No. 88 may be studied. In this instance the cupola charge consisted of cast steel scrap and ferro-alloys only, and the resultant structure was the most markedly dendritic of any met with in the course of this investigation. The reticular pattern revealed in this polished specimen at the lower magnification (Fig. 9) is a thing of beauty, but, alas, not a joy for ever!

Fig. 10, which features the same specimen, in the etched condition, at a magnification of 250 diameters, shows the graphite to be lacy reticular entirely in a matrix of finely divided pearlite. This bar possessed high tensile strength, the average of two determinations in close agreement, being 25.95 tons per sq. in. Only when impact resistance is considered does the material become other than eminently satisfactory; the average of three concordant results being 10.3 ft.-lbs. only.

Tensile strength is undoubtedly an indispensable criterion of quality in cast iron, but surely, since the major inherent weakness of that material is its relatively low resistance to shock, the primary requirement of a high-grade iron is marked improvement in that property. It has been shown that the impact value of grey cast iron is primarily a function of the graphite form. Therefore, an obvious essential in the production of high-grade irons is the adoption of means whereby the presence in the casting of random flake graphite, and the entire absence of a reticular arrangement may be assured. This aim can be realised by the application of a well-known method to be discussed later. Meanwhile, attention may be diverted momentarily to a matter of very practical interest.

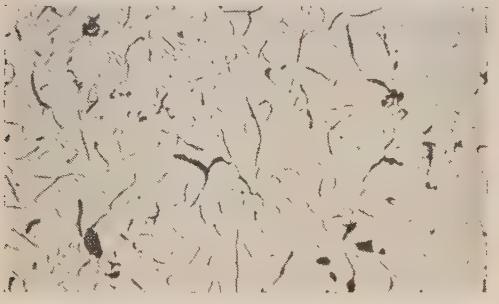

FIG. 7.—TEST-BAR FROM MELT NO. 20. UNETCHED × 50 DIA.

Returned Scrap and Lowered Quality

It had been feared that the inclusion of returned high-strength iron scrap in the cupola charge would be accompanied by deterioration in the physical properties of the resultant cast iron; and that, for consistent production of adequate strength, it might be essential to maintain the low-carbon, graphite-free type of charge. Happily, however, the actual results did not confirm this pessimistic theory. The anticipated increase in carbon content was found to be much less considerable than had been expected, and was not accompanied by appreciable lowering of the physical test results.

In one respect the prognosis was confirmed. Micro-examination revealed that increase in the proportion of returned scrap charged generally produced larger graphite flakes and caused progressive interference with the regularity of the graphite pattern, but the impact values showed this trend to be associated with increased toughness, and this modification in graphite form to be a definite advantage.

Indeed, the standard of the resultant iron is very satisfactorily maintained, despite the utilisation of returned scrap in proportions up to 50 per cent. of the total charge; and that figure probably represents the maximum which will be available in any foundry successfully making high-duty castings for outside sale. The only disadvantage associated with the charging of returned scrap is the progressive lowering of spout temperature which accompanies increase in the proportion used to replace steel scrap. Again, however, this has no significance until fractions in excess of 50 per cent. are employed. (Actually in the home foundry, where most of the castings produced in alloyed, high-duty iron are returnable dies, etc., used in the firm's own forging shops, charges containing 70 to 80 per cent. of returned scrap are successfully in daily use.)

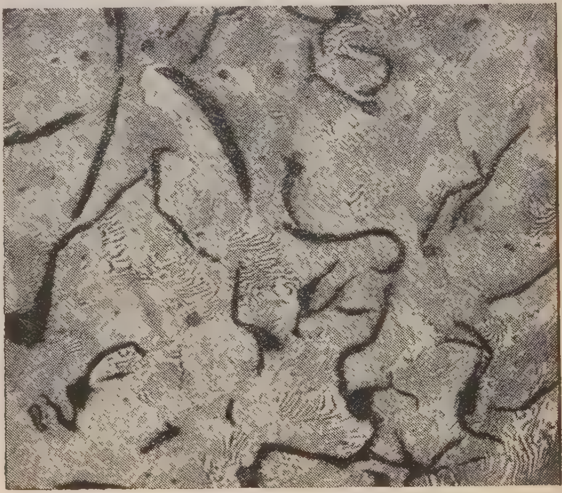

FIG. 8.—TEST-BAR FROM MELT NO. 20. PHYSICAL TEST RESULTS: HARDNESS, 229 BRINELL; TENSILE STRENGTH, 24.36 TONS PER SQ. IN.; IMPACT, 21 FT.-LBS. ETCHED (3 PER CENT. NITAL) × 250 DIA.

Evidence confirming these findings is provided in Tables II, III, IV and V, relating to unalloyed, chrome-molybdenum, molybdenum and nickel-chrome-molybdenum irons respectively. In Table III, for the compilation of which the greatest number of instances was available, the reported trends

MELT	ALLOYING	COST	CHEMICAL COMPOSITION						MELTING LOSS		PHYSICAL PROPERTIES			MICROSTRUCTURE	
Nº	MATERIALS CHARGED	Per Ton of Metals Charged	T C	C C	Si	Mn	S	P	Si	Mn.	Hardness (Brin Nº)	Tensile (Tons/□")	Impact (Ft lbs.)	GRAPHITE.	MATRIX.
			%						%						
24	Silicon Pig (15% Si.)	117/-	2 70	0 57	2 19	1 12	0 093	0 073	22	35	257	20 94	12	Mainly lacy reticular, but many random flakes are also present	Pearlitic
3	Ferro-Alloy Briquettes	84/-	2 71	0 52	2 26	1 23	0 084	0 039	19	23	269	24 12	12	Mainly lacy reticular, but some random flakes are present.	"
4		"	2 68	0 52	2 28	1 16	0 098	0 038	18	28	277	23 96	11	Predominantly lacy reticular only a few random flakes evident	"
5		"	2 60	0 56	2 43	1 22	0 088	0 038	13	24	282	24 12	-	Mainly lacy reticular, some random flakes in evidence	"
6		"	2 85	0 52	2 03	1 10	0 093	0 040	27	31	241	24 20	14	Chiefly in random flakes, but reticular areas are present.	"
9		"	2 65	0 52	2 15	1 01	0 104	0 039	24	37	264	23 84	11	Entirely lacy reticular, in a markedly dendritic distribution	"
10		"	2 72	0 55	2·08	1 17	0·115	0 043	25	27	250	21·20	-	Lacy reticular and normal flakes in fairly equal proportions	"
Average figures for six melts.			2·74	0·53	2 21	1·15	0·097	0·040	21	28	264	23 57	12		
22	Lump Ferro-Alloys	75/-	2 83	0 63	2 39	1 19	0 098	0 050	17	30	257	23 56	-	Mainly in long normal flakes, but a reticular pattern is discernible	"
27		"	2 89	0 46	2 24	1 37	0 098	0·040	16	26	257	23 88	15	As above	"
37		"	2 86	0 53	2 60	1 28	0 089	0 033	9	21	241	22 62	13	Long flake random and short flake reticular in equal proportions	"
Average figures for three melts			2 86	0 54	2 41	1 28	0 095	0 041	14	26	252	23 35	14		
20	Lump Calcium Silicide	97/-	2 78	0 53	2 19	0 46	0 083	0·042	22	31	229	24 36	21	Entirely in the form of long random flakes.	"
21		100/-	2·79	0 73	2 19	1·22	0·091	0·040	21	29	250	25 36	18	Predominantly random but short flake reticular also in evidence	"

In each instance, the balance of the cupola charge consisted of selected steel scrap only.

TABLE 1.—*Influence of Alternative Forms of Alloying Material on the Cost, Properties and Structure of the Resultant Cast Irons.*

TABLE 2 — THE INFLUENCE OF CHARGED RETURNED SCRAP ON THE PROPERTIES AND STRUCTURE OF UNALLOYED IRONS.

MELT	RETD. SCRAP	TEMPERATURE	CHEMICAL COMPOSITION						PHYSICAL PROPERTIES			MICROSTRUCTURE	
Nº	IN CHARGE (%)	AT SPOUT. (°C.)	T.C.	CC	Si	Mn	S	P.	Hardness (Brn. Nº)	Tensile (Tons/□")	Impact (Ft.lbs)	GRAPHITE	MATRIX.
			(%)										
22 27 37	Nil	1420	2·86	0 54	2 41	1 28	0 095	0·041	252	23 35	14	See Table I	Pearlitic
26	19	1400	2·60	0·58	2·43	1·16	0·090	0·039	260	23·68	12	Mainly fine reticular, but medium size, random flakes are present.	"
50	24	1390	2 81	0 56	2·91	1 17	0 096	0 066	262	22 84	13	Chiefly fine reticular, but many "stubby" flakes are in evidence	"
118	48	1380	2·83	0·57	2·68	1·09	0·067	0·034	241	24·30	13·5	Fine reticular, and long random flakes in fairly equal amounts.	"
116	73	1360	2·97	0·56	2·33	1·17	0·070	0·042	264	22·22	14	Short flake reticular, and long flake random, equally in evidence.	"
13	98	1340	2·93	0·51	2·25	1·07	0·113	0·058	241	21·56	–	Mostly in long random flakes, but a reticular pattern is discernible	"

Balance of each cupola charge:– selected steel scrap and/or ferro-alloys only.

TABLE II.—*Influence of Charged Returned Scrap on the Properties and Structure of Unalloyed Irons.*

MELT.	RETD SCRAP	TEMPERATURE	CHEMICAL COMPOSITION				
Nº	IN CHARGE (%)	AT SPOUT (°C)	C.	Si.	Mn.	S.	P.
			(%)				
79b	Nil	1430	2·48	2·74	1·37	0·059	0·059
106b	Nil	1420	2·69	2·59	1·20	0·067	0·025
Average for two melts:-		1425	2·59	2·67	1·29	0·063	0·042
76	47	1400	2·86	2·58	1·03	0·061	0·070
97	"	1390	2·71	2·55	1·38	0·054	0·047
104b	"	1390	2·83	2·80	1·16	0·110	0·026
115	"	1400	2·80	2·04	1·20	0·060	0·036
Average for four melts:-		1395	2·80	2·49	1·19	0·071	0·045
90	67	1370	3·13	2·48	1·54	0·049	0·062
100	66	1350	3·25	2·36	1·32	0·073	0·039
103	"	1360	3·10	2·27	1·38	0·075	0·056
Average for three melts:-		1360	3·16	2·37	1·41	0·066	0·052
107	99	1340	3·03	2·73	1·40	0·066	0·041
114	"	1330	3·09	2·41	1·04	0·042	0·050
Average for two melts:-		1335	3·06	2·57	1·22	0·054	0·046

Balance of each cupola charge

TABLE III.—*Influence of Charg and Structure of Ch*

MELT	RETD. SCRAP	TEMPERATURE	CHEMICAL COMPOSITION.				
Nº	IN CHARGE. (%)	AT SPOUT. (°C)	C.	Si.	Mn.	S.	P.
			(%)				
32	Nil.	1430	2·89	2·29	0·97	0·089	0·031
51	"	1420	2·54	2·75	1·42	0·074	0·059
Average for two melts:-		1425	2·72	2·52	1·20	0·082	0·045
35	17	1400	2·93	2·35	1·16	0·062	0·059
41	25	1390	2·66	2·85	0·91	0·080	0·042
36	38	1370	2·91	1·87	0·73	0·079	0·032
54	41	1360	2·93	2·40	1·25	0·089	0·055
53	56	1370	2·72	2·33	1·19	0·080	0·059

Balance of each cubola charge:–

TABLE IV.—*Influence of Charge and Properties of*

MELT Nº	RETD. SCRAP IN CHARGE	TEMPERATURE AT SPOUT	CHEMICAL COMPOSITION.								PHYSICAL PROPERTIES			MICROSTRUCTURE.	
			C.	Si	Mn	B.	P.	Ni	Cr.	Mo.	Hardness	Tensile	Impact.	GRAPHITE.	MATRIX.
	%	°C	%								(Brn. Nº)	(Tons/□")	(Ft lbs)		
48	26	1420	2·90	2·47	1·06	0·082	0·054	1·18	0·64	0·92	334	31·50	–	Test pieces lost: no specimen available for examination	
61	31	1400	2·94	2·31	1·32	0·068	0·057	1·16	0·60	0·97	341	27·28	12	Mainly fine flake reticular, but some random flakes are present	Fine pearlite; approx. 25% of field 'acicular.'
63	47	1380	3·08	2·08	1·02	0·083	0·043	0·96	0·49	1·06	338	27·00	–	Very fine reticular. Small grain size denotes much undercooling.	Fine pearlite; 10% of field 'acicular'; some carbide.
67	″	1380	2·74	2·66	1·16	0·058	0·087	1·10	0·65	0·83	318	29·80	12	Mainly fine flake reticular, but many random flakes are present.	Fine pearlite; traces of free carbide present.
Average of two melts:–		1380	2·91	2·37	1·09	0·071	0·065	1·03	0·57	0·95	328	28·40	–		
64	78	1370	3·03	2·21	1·02	0·071	0·057	1·00	0·62	0·89	288	27·50	18·5	Mainly medium random flakes, but a reticular pattern is traceable	Fine pearlite, roughly 10% of field 'acicular'
65	″	1360	2·99	2·24	0·96	0·068	0·130	0·94	0·55	0·80	286	26·52	14·5	Chiefly in random flakes, but a reticular pattern is discernible	Finely-divided pearlite, entirely.
66	″	1370	3·02	2·45	1·20	0·066	0·070	1·06	0·68	0·89	299	28·06	16	Predominantly in random flakes; background only faintly dendritic.	Finely-divided pearlite, entirely.
68	″	1350	2·90	2·50	1·09	0·064	0·082	0·90	0·59	0·86	341	27·28	12·5	Mostly fine flake reticular, but some random flakes are present	Fine pearlite, about 10% of field 'acicular.'
69	″	1350	3·05	2·31	0·98	0·076	0·081	1·04	0·60	0·85	315	28·14	12	Normal random, and fine flake reticular, equally represented.	Fine pearlite; approx. 5% of field 'acicular.'
Average of five melts:–		1360	3·00	2·34	1·05	0·069	0·084	0·99	0·61	0·86	306	27·50	14·7		

Balance of each cupola charge:–selected steel scrap and ferro-alloys only.

TABLE V.—*Influence of Charged Returned Scrap on the Properties and Structure of Nickel-Chrome-Molybdenum Irons.*

TABLE 6 — THE INFLUENCE OF LADLE ADDITIONS OF GRAPHITE

MELT Nº	NATURE OF THE LADLE ADDITION	HISTORY OF THE MELT.	CHEMICAL COMPOSITION.						PHYSICAL PROPERTIES			MICROSTRUCTURE	
			TC	CC	Si	Mn	S	P	Hardness	Tensile	Impact.	GRAPHITE	MATRIX
			(%)						(Brn Nº)	(Tons/□")	(Ft lbs)		
139a	————	As tapped, poured just prior to inoculation	2·58	1·41	1·55	1·09	0·079	0·038	299	unmachinable		Mottled fracture Some lacy reticular graphite in centre	Pearlite + Cementite
139b	Ground Electrode. (Thro' - Nº44 mesh)	Poured two minutes after inoculation	2·65	0·60	1·53	1·08	-	-	210	20·80	18	Long random flakes only	Pearlitic
138a	————	As tapped; poured just prior to inoculation.	3·02	0·52	2·13	1·05	0·110	0·040	243	23·28	12	Mainly lacy reticular, but some random flakes present	″
138b	Ground Electrode. (Thro - Nº44 mesh)	Poured two minutes after inoculation	3·09	0·50	2·17	1·04	-	-	219	23·36	18	Long random flakes only.	
142a	————	As tapped, poured just prior to inoculation.	2·99	0·53	2·22	1·02	0·100	0·041	239	24·40	17·5	Chiefly random, but areas of lacy reticular graphite present	
142b	Granular Electrode (Thro - 3/8" mesh)	Poured, two minutes after inoculation	3·16	0·53	2·21	1·01	-	-	215	22·46	21	Long random flakes only	″
143a	————	As tapped; poured just prior to inoculation	2·87	0·59	2·04	0·84	0·100	0·033	237	24·64	15	Mainly short flake reticular but many random flakes also.	″
143b	Lump Electrode.	Poured two minutes after inoculation	2·90	0·56	2·05	0·84	-	-	233	25·12	23	Medium flakes in random distribution.	″

Each cupola charge consisted of selected steel scrap and ferro-alloys only.

In each instance, the weight of graphite added = 0·2% of the weight of metal treated.

TABLE IV—*Influence of Ladle Additions of Graphite.*

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PROCEEDINGS, VOLUME XXXV.

The Table marked Table IV on the second insert sheet facing page 204, should read Table VI.

TABLE 7 :—THE INFLUEN

MELT Nº	Grade of the added Ferro-Silicon	Percentage of added		HISTORY OF THE MELT	CHEMIC	
		Material	Silicon		T.C	CC
133a	————	Nil.	Nil	As tapped; poured just prior to inoculation.	2·76	0·50
133b	45-50 % Silicon. (Thro 1/8 mesh)	0·26	0·125	Poured, two minutes after inoculation.	2·76	0·48
131b	″	0·53	0·25	Inoculating addition made at cupola spout.	2·87	0·49
126b	″	0·79	0·375	″	2·62	0·54
25	″	1·05	0·50	″	2·92	0·57
132b	85 % Silicon (Thro. 1/4 mesh)	0·90	0·75	″	2·65	0·69
140a	————	Nil	Nil	As tapped, poured just prior to inoculation.	2·72	0·70
140b	85 % Silicon (Thro. 1/4" mesh)	0·60	0·50	Poured, two minutes after inoculation	2·66	0·65
140c	″	″	″	Poured, seven minutes after inoculation	2·69	0·57
140d	″	″	″	Poured, twelve minutes after inoculation	2·67	0·52

Each cupola charge consisted

TABLE VII.—*Influence of*

TABLE 8 :— THE INFLU

MELT Nº	NATURE OF THE LADLE ADDITION.	Percentage of added			CHEMICAL		
		Material.	Silicon	Calcium	T.C	C.C	Si
123	Calcium Silicide. (Thro'–1/8" mesh.)	0·20	0·12	0·06	2·80	0·46	3·12
117	As above	0·40	0·24	0·12	2·86	0·58	2·67
136	As above	0·80	0·48	0·24	2·63	0·61	2·48
134	Cal.-Mang.-Silicon. (Thro'– 1/8" mesh.)	0·45	0·24	0·08	2·57	0·65	2·05
135	Sil.-Mang.-Zirconium. (Thro'– 1/4" mesh)	0·70	0·50	-	2·74	0·68	1·59

Each cupola charge consisted of selected

TABLE VIII.—*Influence*

are most apparent. It will be observed, however, that the control exercised over graphite form by the melting of graphite-bearing scrap is not absolute, and considerable variation can occur even with the highest proportions of charged scrap. The need, therefore, for the adoption of some method by which the absence of dendritic structures can be assured is still outstanding.

American Research

Much effort has been expended in investigation of the exact nature of the process of graphite formation in grey irons. At the present time, the thanks of all interested are particularly due to the metallurgists of the U.S.A., whose latest researches have been so elucidating that part of this Paper will be devoted to a *résumé* of the most interesting recent publications.

D'Amico and Schneidewind have studied the influence of under-cooling on the solidification and graphitisation of grey irons. In their earlier Paper,[6] these co-authors describe experiments conducted on a wedge casting. The actual temperatures of solidification in various sections were observed, and it was found that rapid rates of cooling gave rise to appreciable under-cooling. Moreover, the faster the cooling rate—that is, the thinner the section studied—the greater the degree of under-cooling exhibited.

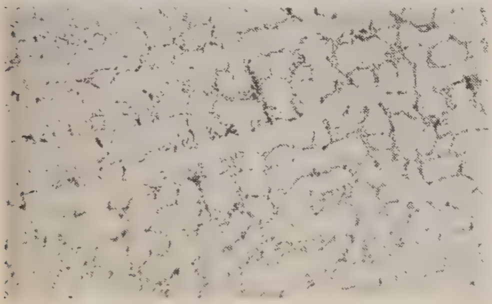

FIG. 9.—TEST-BAR FROM MELT NO. 88. UNETCHED × 50 DIA.

In the micro-structure of the wedge, widely differing types of graphite were observed. As the section thickness decreased, the graphite form gradually changed from long flakes in random distribution to very fine flakes in inter-dendritic arrangement. With sufficiently rapid rates of cooling, graphitisation was suppressed, with the formation of mottled and white irons. Similar examinations of other wedges showed that variations in composition, the addition of alloys and the application of ladle treatments merely altered the location, that is, the thickness of the section, in which the various graphite types were found—their positions relative to one another were unchanged.

Subsequent work,[7] in which use was made of specimens poured within heated metal moulds, confirmed these findings, and further demonstrated that the change from normal flake graphite to very fine graphite in reticular arrangement is a gradual transition controlled principally by the degree of undercooling experienced. Study of the effect of ladle additions of calcium silicide revealed that this treatment greatly extends the range of under-cooling over which graphite of the normal flake type is formed, the degree of under-cooling necessary for the production of mottled and white irons being markedly increased. That is to say, in iron so treated, the tendency to graphitise, or, the urge to form grey iron, is much stronger than in an untreated iron of the same composition.

Graphite Formation

The process of graphite formation has been further studied by Eash,[8] whose preliminary work demonstrated that inoculated, low-carbon irons freeze at higher temperatures, and exhibit shorter eutectic arrests, than do untreated but otherwise similar irons. These differences in behaviour were observed to coincide with the production of normal flake, and fine reticular graphite in the respective sets of test-bars. This suggested that the eutectic of the inoculated irons was freezing differently from that of the untreated irons. To obtain more direct evidence, specimens poured from "as-melted" and inoculated irons were each quenched from just below the observed eutectic temperature, that is, immediately after completion of freezing in each case.

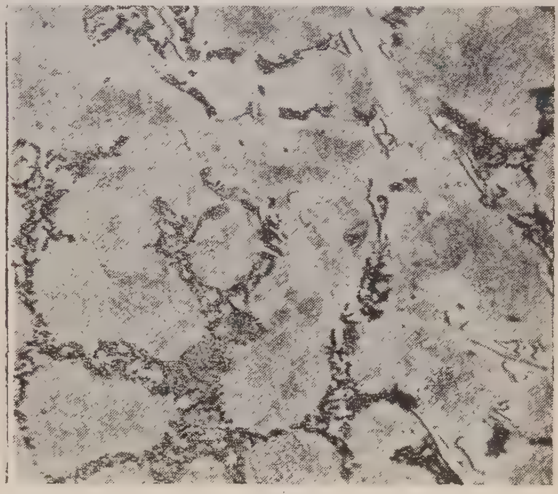

FIG. 10.—TEST-BAR FROM MELT NO. 88. CHEMICAL ANALYSIS: T.C, 2.66 PER CENT.; C.C, 0.61; SI, 2.41; MN, 1.29; S, 0.056; P, 0.033 PER CENT. PHYSICAL PROPERTIES: HARDNESS, 277 BRINELL; TENSILE STRENGTH, 25.95 TONS PER SQ. IN.; IMPACT RESISTANCE, 10.3 FT.-LBS. ETCHED (3 PER CENT. NITAL) × 250 DIA.

The structure of the former specimen consisted of the primary dendrites rendered martensitic by the quench, with carbide in massive and eutectic form in the interstices. An identical bar, cooled in the mould, was completely grey with fine graphite in inter-dendritic distribution. Obviously, this had been formed by decomposition of the carbide originally present. (An inspection of Fig. 10 which illustrates the most markedly dendritic structure of personal experience will reveal the presence of carbide in intimate co-existence with the lacy reticular graphite. This provides confirmation of the mode of formation postulated above.) The quenched bar from the inoculated melt was completely grey, the graphite being entirely in the flake form, as was that of the companion bar cooled in the mould. This graphite had evidently formed directly from the liquid.

A further bar from the inoculated melt, quenched from a temperature immediately above the freezing point of the eutectic, was found to exhibit a mottled fracture of most peculiar type. Around the edge of the section the structure was completely grey, containing flake graphite. Adjacent to this outer rim, a mixture of eutectic carbide and specks of graphite occupied the dendritic interstices. The central area was grey, with fine graphite in very reticular arrangement. This remarkable structure is explainable in the light of the information already gleaned. At the instant of quenching the exterior of the bar was completely solid and flake graphite had formed directly. In the interior, however, where freezing of the eutectic liquor had not yet begun, the quench caused formation of the metastable carbide phase. In the outer annulus, through which heat transfer was rapid, subsequent breakdown of the carbide was limited, but, in the centre, where cooling was less drastic, a greater degree of decomposition was possible, the resultant grey iron containing fine reticular graphite only.

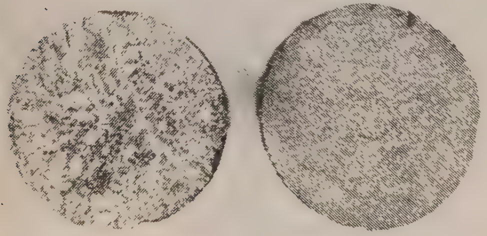

FIG. 11.—1.2-IN. DIA. TEST-BARS.

Eash suggests that inoculation produces nuclei which initiate the separation of graphite from the liquid with the formation of random flakes. Following successful inoculation by the addition of powdered graphite, he considers it probable that the inoculating nuclei are particles of graphite. He states: "It is entirely possible that late ferro-silicon additions produce a shower of minute graphite particles in the ladle due to localised silicon concentrations reducing the carbon solubility."

The following are among the conclusions reached by this investigator:—

(*a*) "Grey irons, having fine graphite in a dendritic pattern, solidify in the metastable iron-carbide system as white irons. The eutectic carbide subsequently decomposes in the solid state to form iron and graphite."

(*b*) "Ladle inoculated grey irons, having random flake graphite, solidify in the stable iron-graphite system. The flake graphite forms during the freezing of the graphite-austenite eutectic."

(*c*) "It is believed that inoculation produces graphite nuclei which cause the iron to solidify in the iron-graphite system."

The Nuclear Theory

The nuclear theory is given further support by Massari and Lindsay.[9] By experiments on low-silicon irons, these collaborators have demonstrated that ladle additions of graphite exercise a very potent graphitising influence, and can produce startling alterations in the structure of chill cast test-pieces. No attempt can here be made to summarise the vast amount of accurate work described in this Paper, which should be read in its entirety by all interested. It is sufficient to state that all of the results are explainable on the basis of the existence of graphite nuclei and strongly support the theory that one of the basic factors influencing the graphitising behaviour of an iron is the number of graphite nuclei present at the moment of solidification.

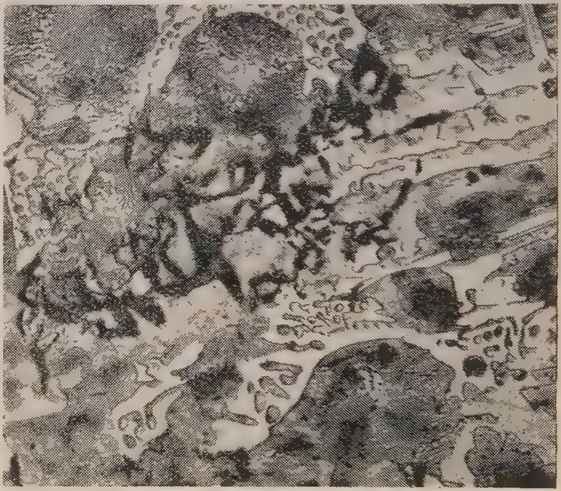

FIG. 12.—TEST-BAR FROM MELT NO. 139*a*. PHYSICAL PROPERTIES: HARDNESS, 299 BRINELL; TENSILE STRENGTH AND IMPACT, UNMACHINABLE. ETCHED (3 PER CENT. NITAL) × 250 DIA.

It is now realised that low-carbon irons tend to exhibit dendritic structures with the graphite present as fine, inter-dendritic deposits. It has been found that this arrangement, while exercising no appreciable influence on tensile strength, greatly reduces the resistance to shock. Much has been learnt as to the formation of graphite, and foundrymen have been informed of the means by which the production of random graphite may be assured. The writer's own experiences in the employment of inoculation technique may now be described.

Inoculation Technique

Supplies of graphite in the form of discarded electrode, in the lump, granulated and crushed conditions, were available, and use was first made of the powdered material. Test-bars poured before and after the addition proved this to be completely successful in producing random graphite and improved resistance to impact. In order to obtain unmistakeable proof of the potency of such additions, it was arranged to tap a low-silicon iron calculated to yield a mottled structure in the 1.2 in. dia. bar. Clear evidence of the inoculating effect, capable of interpretation by any foundryman, would then be provided by photographic reproduction of the fractures of the bars poured before and after inoculation. These are featured in Fig. 11, which shows the respective fractures, left and right, of the bars poured from melt No. 139.

For the benefit of the metallurgically trained, Figs. 12 and 13, which show the etched structures of the respective bars, each at a magnification of 250 diameters, have been prepared. It will be noted that the graphite present in the mottled bar is in the form of small interlacing deposits obviously formed from the carbide, which is a prominent constituent of the microstructure. The inoculated bar, however, contains graphite of the normal flake type only, and no free carbide is present. Such striking alteration in structure, explainable only if complete change in the process of graphite formation be visualised, cannot, in this instance, be attributed to change in composition, since the increase in carbon content accompanying inoculation was only 0.7 per cent.

Subsequent experiments proved granular and lump electrode to be successful inoculants also, and full details of the melts concerned are quoted in Table VI. The results show that inoculation by ladle addition of graphite is a perfectly practicable proposition. Attention is particularly drawn to the case of melt No. 143, in which lump electrode was employed, and where, though the carbon increase was only 0.03 per cent., a definite alteration in graphite form was produced and a substantial increase in impact resistance obtained.

For ladle addition, electrode graphite is probably most suitable in lump form. The inoculating effect is potent, increase in the carbon content of the metal is slight, recovery of unconsumed electrode is easy and efficient, and pouring suffers no inconvenience from the presence of electrode stubs on the metal surface.

Ferro-Silicon Treatment

Experiments were conducted in the addition of ferro-silicon in various proportions to the metal tapped from graphite-free charges, and the results are presented in Table VII. They indicate that from the viewpoint of efficient inoculation, there is no virtue in excessive ladle additions of this material. Nevertheless, the greater the proportion of silicon added in the ladle, the more positive is the control over final composition. The disadvantage of heavy additions, however, is the appreciable cooling effect which they exercise on the contents of the ladle, but this may be minimised at no extra cost by the utilisation of rich alloys.

Influence of Time.—Transatlantic opinion favours prompt pouring after inoculation on the ground that the effect decreases with the passage of time, and 10 to 20 min. has been quoted as the period of grace. To check the practical significance of this finding an opportunity was taken of melting graphite-free charges, tapping a considerable bulk (25 cwts.) into a hot vessel, and inoculating with an 0.5 per cent. silicon increase in the ladle. Test-bars were cast before, and at time intervals after, inoculation. These were poured from shanks filled at the ladle, and, under control by optical pyrometer, all were cast at the same temperature.

The results, which are those for melt 140, show that inoculation effected the usual change in graphite form and increase in impact value. They also demonstrate that the passage of time did not coincide with reduction in the extent of these improvements, and, since the period studied is greater than that normally elapsing between inoculation and complete disposal, the fears of the writer were allayed.

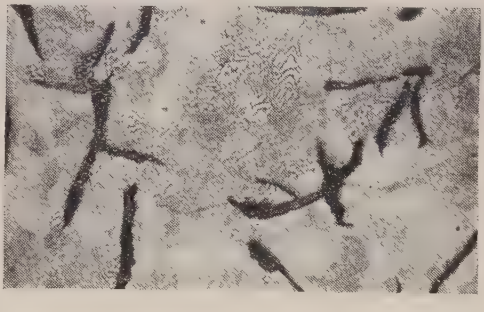

FIG. 13.—TEST-BAR FROM MELT NO. 139*b*. PHYSICAL PROPERTIES: HARDNESS, 210 BRINELL; TENSILE STRENGTH, 20.80 TONS PER SQ. IN.; IMPACT, 18 FT.-LBS. ETCHED (3 PER CENT. NITAL) × 250 DIA.

Other inoculating materials, all relatively expensive, have been tried on a small scale, and such results as the author has available are quoted in Table VIII.

The writer favours inoculation by ferro-silicon for the following reasons:—(1) The use of a silicon-containing material gives increased control of final composition and reduces the risk of erratic results, and (2) ferro-silicon is as effective as, and more economical than, any of the alternative materials tried. Indeed, its addition in the ladle creates an actual saving since this operation, efficiently performed, incurs less loss of silicon than does cupola melting.

When dealing with normal production taps from charges containing 50 per cent., or more, of returned scrap, the writer's practice is to add ferro-silicon (45 to 50 per cent. Si), small enough to pass a ⅛-in. mesh and in amounts sufficient to add 0.25 per cent. of silicon in the ladle. Where there is particular need for exact control of final composition, the equivalent of 0.5 per cent. silicon is added, use being made of a rich alloy (85 per cent. Si) to reduce the bulk of the addition.

The material should always be dry, and can be heated with advantage. It may be added in the spout or directly to the metal in the ladle. In either case, it should be added in a thin stream, the receiving surface being kept quite bare. If the particles of ferro-silicon come in contact with slag or if the addition be made hurriedly, the efficiency of the operation may be seriously lowered, as was the case with melt 140, where the yield was only 70 per cent. of the possible.

Recommended Procedure

A diagrammatic illustration of recommended procedure is presented in Fig. 14, which depicts the technique employed and the results obtained on the occasion of a recent melt. It also provides the promised sketch of the cupola, and attempts to portray, in somewhat ideal fashion, the distribution of metals and fuel in the fully-charged furnace.

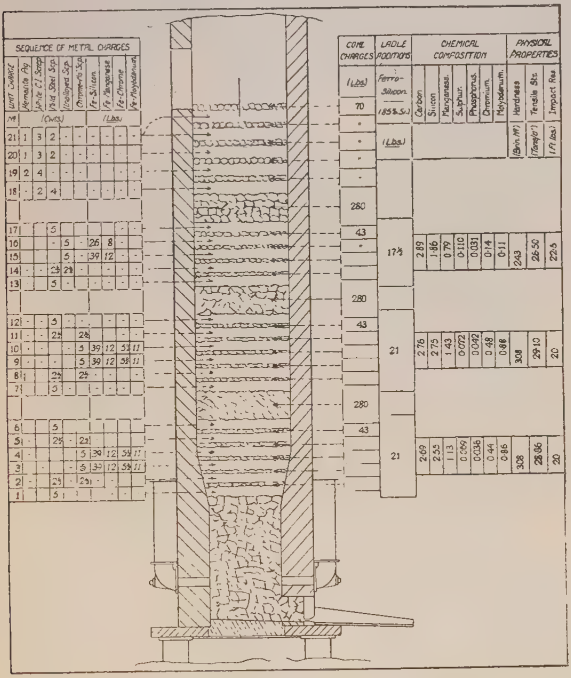

FIG. 14.

Full details of the metal charges are quoted in the left-hand table, and the method of controlling composition is shown. The complete charge is regarded as a succession of groups, these corresponding to the individual taps. Each group, in turn, is composed of several unit charges, so arranged that the alloying agents of each group are concentrated centrally. Returned scrap comprises 50 per cent. of the total charge, yet the borders of adjacent groups consist solely of steel scrap and sharp separation of group from group is promoted.

Coke is charged in very light unit, and fairly generous separating, layers. The latter perform a double function. Their presence at strategic intervals ensures regular restoration of bed height and simultaneously assists in the provision of sharp separation between groups. Calculation will show that the ratio of coke to metals charged is approximately 1 to 7. This figure may spell extravagance to conventional judgment, yet the need for really adequate coke allowance with high-steel charges cannot be over-emphasised. The beginner will be well advised to err on the side of generosity, and the proportions quoted will serve as a useful guide to safe procedure.

The ladle additions are detailed and the final analyses and physical test results quoted. It will be observed that the chrome-molybdenum irons are very similar in composition and virtually identical in properties. The unalloyed metal is satisfactory in all respects and the alloy lag has been slight.

Conclusion

It is the author's hope that this Paper, by inspiring greater interest in the impact resistance of grey irons, will hasten the adoption of standard procedure for the evaluation of this property. Eventual inclusion of impact requirements in the B.S. Specification covering high-duty iron castings would do much to raise the standard of this important product of our industry.

For permission to present this Paper, thanks are due to the directors of Babcock & Wilcox, Limited. The reported investigation was possible only by reason of the fact that excellent resources were at the disposal of the writer. For the enthusiastic co-operation of his colleagues in the Chemical, Metallurgical and Mechanical Test Sections of the B. & W. Research Department, thanks are tendered to Mr. W. G. Marskell, Superintendent. Individual acknowledgment, however, must be made of the assistance rendered by Mr. J. S. Vipond, also of the Research Department, who has acted throughout as guide, photographer, and friend, and whose professional skill has so adorned this Paper. Finally, and once again, to Mr. Robert O. Patterson, Foundries' Superintendent, for his constant support, helpful advice and inspiring encouragement, the warm thanks of the author are publicly expressed.

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DISCUSSION

LANCASHIRE BRANCH

MR. A. L. KEY, opening the discussion, said that initially he had been interested in the height which had been found to be best for the coke bed and the pressure behind the tuyeres employed to blow the cupola described. That it was a profitable practice was justified by the results obtained. Had Mr. Braidwood tried any alternatives? He (the speaker) had on many occasions melted high steel charges in the cupola using up to 60 per cent. steel mixtures, and he had found that the blast pressure quoted, used in the size of cupola described, would be liable to give rise to trouble through "frothing." He had found that when the bed was lowered, and a softer blast employed, better results were obtained than with a higher bed and a higher blast. Of course, the end justified the means, and Mr. Braidwood had undoubtedly arrived at a very successful issue.

To the majority of foundrymen, high-duty cast irons were of the greatest interest. Unfortunately, however, many foundries could not attempt the production of such irons, since they were engaged in satisfying the demands of a commercial market, and their customers would object to the high prices asked for some high-duty materials. In his own case, without the employment of inoculation technique, he had frequently obtained results in excess of 19 tons per sq. in. from ordinary pig-iron plus steel mixtures.

Height of Coke Bed

MR. BRAIDWOOD, referring to the charged bed of coke, said that several members had produced their notebooks when he referred to 48 in., but had put them aside again when he stated that the height was subsequently reduced to 36 in. This latter figure, nevertheless, still represented a fairly high bed, but his advice was "never spare coke when melting high-steel charges." The beginner should be content to err on the safe side. Later on, attempts could be made to economise in coke without detriment to metal quality or to the reliability of the production procedure. His aim had been initially to determine, and eventually to demonstrate, that the production of high-duty irons was a project which could successfully be undertaken by any foundry equipped with the normal facilities and possessing the will to exercise control. He hoped his work had shown clearly that there was nothing mystical or miraculous about the production of high-duty cast irons, and he felt that the sooner the industry fully realised this the better.

The melting unit which he had employed was just that type of cupola which would probably be found in almost any foundry. The blast pressure ($\frac{3}{4}$ lb. per sq. in.) was not excessive, and he was not at all inclined to believe that, if he lowered the pressure, better results would be achieved; actually he held the opposite opinion. A point to remember was the influence of blast pressure upon the actual bed height, that is, the bed which is maintained when the cupola is in operation. With inadequate blast pressure one might charge a high bed, but melt no metal until the bed height had been very substantially reduced.

Life of Cupola Lining

His primary object had been to obtain consistent production of high-duty cast iron, and he had found that an initially high bed did not give high carbon. Wear on the lining had not been pronounced; indeed, when the cupola was relined recently, after completion of the work described, it was the first rebuild in six years, and relining had been necessary only because the bricks in the cupola shaft had been worn dangerously thin. The melting of high-steel charges, therefore, did not necessarily incur high charges for refractory materials. He had never experienced any trouble due to frothing, and he had found that high-duty cast irons, melted as described, were very castable and peculiarly fluid. It was his practice always to use hot, clean vessels, and he had no difficulty in handling the metal, the fluidity of which could be judged from the fact that the test-bars were run through a semi-circular ingate of $\frac{1}{4}$-in. radius.

It could be stated, however, that if the advice given in the Paper was not followed, reliance being placed upon conventional ideas about coke, then, after tapping out several charges, lowered carbon, silicon and manganese contents would result, and a whole host of troubles would ensue. Again, his advice was, "Be sensible about coke, and the results will be satisfactory."

He could not agree that prices need be excessive. Actually, the material cost of unalloyed high-duty iron, produced as described, was lower than that of ordinary cast iron from pig and scrap charges. Of course, there was the cost of supervision to consider, and this was always difficult to assess. For example, the metallurgist and his laboratory might be utilised more on the control of several tons of high-duty iron than on that of several hundred tons of ordinary cast iron.

He fully endorsed Mr. Key's remarks concerning the helpfulness of a laboratory, and he realised his own good fortune in having research results handed out to him, as it were, "on a plate." A laboratory, indeed, is an essential feature of the modern foundry; yet it need not be elaborate and, in good hands, could very soon much more than pay its way.

Inoculation Procedure

MR. A. L. KEY, referring to the method of inoculation by addition of graphite, asked whether this was carried out in the spout or in the ladle. Further, was Mr. Braidwood in possession of data respecting the relative merits of high-duty cast iron and a straight cast iron at elevated temperatures; for instance, under both alternating and constant temperatures? The cupola he was using at the present time was one he had made according to his own design. It had a bed, 2 ft. 6 in. above the tuyeres. With a maximum blast of eight ounces on one type of material, and reduced to seven ounces on a general type of material, the carbon very seldom exceeded 3 per cent. The average carbon content of all material was between 2.9 and 3.1.

MR. BRAIDWOOD said that the graphite addition was very easily made; the ladle was filled, the surface skimmed, and a lump of electrode thrown in. As was stated in the Paper, the favoured inoculant was ferro-silicon, since such an addition gave some control of composition at the spout. In the case of the first tap, however, there was always a tendency for the metal temperature to be somewhat lower than normal, and the making of a cold addition had disadvantages. Moreover, since the composition of the first-tapped metal could always be very reliably regulated, there was not the same need then for the degree of control afforded by spout additions of ferro-silicon. For these reasons the standard daily practice at Renfrew is to inoculate the first tap by graphite addition and the subsequent taps by additions of ferro-silicon. Consumption of lump electrode was not heavy, and the average piece lasts for many days.

Common Irons Materially Improved

He recounted a recent experience which had demonstrated the practical benefits which might be derived from inoculation of ordinary cast irons by graphite addition. Castings for structural and miscellaneous applications were now being poured in a "Grade C" iron of high phosphorus content (1.2 per cent. P), and carbon content had fallen to around 3.1 per cent. These changes in analysis were found to coincide with an outbreak of trouble in the form of "sinking," and micro-examination of the affected castings showed the graphite to be present in a recognisably reticular arrangement. It was decided to test the influence of inoculation, and a piece of electrode was floated in every vessel of molten iron. Immediate improvement resulted, and the trouble, which had been persistent, faded out, though the analysis of the irons was unchanged. The graphite was now found to be completely random.

The following explanation of this effect was offered. Graphite of the reticular type, formed after completion of solidification, did not assist in offsetting the shrinkage which accompanied solidification and which promoted "sinking." Random flake graphite of the normal type, however, was precipitated from the liquid in the interval between the commencement and the completion of solidification, and the expansion accompanying its formation was therefore of active assistance in minimising the solidification shrinkage and preventing "sinks." It was now his routine practice to maintain a lump of electrode in every vessel, and the results continued to be satisfactory. This procedure, which was simple, convenient and inexpensive, was recommended as well worth trial by anyone who might be experiencing similar trouble as a result of present-day conditions.

Tuyere Area Considerations

MR. J. JACKSON said that he wondered if there was any particular advantage in working the tapered shape as compared with a straight-walled cupola. He noticed that it was a cupola with a very small well, that is, with a low capacity for retaining molten metal. Did Mr. Braidwood consider this to be of advantage? He understood Mr. Braidwood to give the size of the tuyeres as 5 in. by 4 in. Had he found an increased tuyere area beneficial or otherwise? It was an area which was conforming to the old theoretical basic line which had been laid down for many years in the ratio of 1:5, and which he (the speaker) must confess he had now dismissed from consideration. In the foundry with which he was associated, they were now working at a ratio of something like 8 or 9 to 1, which had been found to be more beneficial.

Tapered Linings

MR. BRAIDWOOD said that during his short stay in the Lancashire area he had been gratified to discover that several people not only had read, but had studied, a previous Paper of his, entitled "Melting Practice in a Large Engineering Iron Foundry."* Indeed, he had been the interested guest of one local foundry in which the installation of a new melting plant, modelled exactly on the Renfrew layout, had just been completed.

His point in referring to this earlier Paper was that Mr. Jackson's inquiry with regard to the tapered cupola lining was very fully answered therein. Briefly, however, it might be recalled that the tapered contour was designed to save coke and to economise in patching material, as well as to promote more uniform combustion of the fuel and greater regularity in melting.

In the cupola at present under discussion, the diameter in the shaft was 42 in., while that in the region of the bed was 32 in. Calculation would show that the volume of a 32-in. dia. cylinder was approximately 60 per cent. of that of a 42-in. dia. cylinder of equal height. In this instance, therefore, the taper effected a saving in bed coke equal to 40 per cent. of that weight which would have been required to give the desired height in the straight-walled cupola. The tapered lining also permitted greater ease of blast penetration, since the ports of entry were much nearer to the centre of the cupola cross-section. These advantages, together with some others, were discussed in greater detail in the earlier Paper, to which reference might be made by those interested.

Small-Capacity Cupola Well

The capacity of the well of the cupola in use was somewhat small, and he would have preferred to have it rather greater, but this could not be done without undertaking extensive structural alterations. The diagram, of course, showed the lining in perfect shape, though in actual service it was never quite like that. His practice was to allow the walls below tuyere level to wear wide and thus increase the capacity of the well. By this means he had made it possible to hold more than a ton of molten iron in the cupola, and, by delaying each tap till the last possible moment, they were able to obtain 30 cwts. of metal before the well was drained.

There was only one row of four tuyeres, each measuring 5 in. by 4 in., and thus giving a total tuyere area of 80 sq. in. The cross-sectional area of the cupola at the same level (32 in. dia.) was 804 sq. in., and the ratio of tuyere area to furnace area was therefore approximately as 1:10. This ratio, however, had not been deliberately established nor determined by any consideration of theory. He simply had utilised the furnace as it stood and as it had been working for some years previously, in order to satisfy himself that high-duty irons could successfully be melted in a serviceable cupola of ordinary type.

MR. S. G. HARRISON asked for further information concerning the height of the cupola from tuyeres to charging door. From the drawing, this appeared to be rather high, probably in order to obtain all the pre-heating of the charges possible. Was any specific size of coke used, or was it put into the furnace at random as received?

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* Proc. I.B.F., Vol. XXXII, 1938-39, p. 405.

Also, was any special type of coke employed? He assumed the melting rate of the furnace should be approximately 3 tons per hr. Would this apply to all steel melts? He was particularly interested in the six years' lining life, because, in his own experience, he would be thankful to get about one-quarter of that result. Was it due to the total amount of metal going through the furnace per day being small; were there five tons or 25 tons per day being melted?

MR. BRAIDWOOD said that since the diagram was constructed to scale, his questioner would be able to calculate all of the dimensions from the illustration when the Paper was published. (Actually, the dimension queried is 17½ ft.)

A Durham coke of standard quality was used. It was of normal size, and was charged to the cupola as received. The rate of melting was fully 3 tons per hr. on high-duty cast irons and the total daily melt was in the region of 5 to 6 tons.

Lining Life

He was rather proud of the life of his linings. It was a theory of his that if the cupola was built with any good brick which would withstand abrasion in the shaft, long life might be expected. It was his practice to make a thorough repair in the melting zone after each blow, using gauge sticks to ensure maintenance of the desired dimensions. It could be argued, of course, that with old linings extra ganister might be necessary in amounts sufficiently expensive to outweigh the cost of a complete re-build. His refractories cost, however, was not high and figures with regard to the average amounts of ganister used on the Renfrew cupolas were quoted in the Paper to which reference had already been made.

Heat-Treatment

MR. H. P. HUGHES stated that in his opinion the Paper would have been the acme of perfection if it had dealt with the heat-treatment of the irons mentioned, and also with the moulding technique used in the actual production of castings. Could Mr. Braidwood give any information concerning the advertised virtues of certain graphitisers and of specialised metals made under licence?

MR. BRAIDWOOD said that he had deliberately made no statements with regard to heat-treatment and had quoted only those results obtained on bars tested in the "as-cast" condition, chiefly because he did not wish to divert attention from the main features of his Paper but also for the very sufficient reason that he had no space available for further matter. He did feel, however, that heat-treated, alloyed irons were destined to become of ever-increasing importance. It was routine practice at Renfrew to harden certain fully-machined dies, poured in alloyed high-duty cast iron, by quenching in oil. By this means the hardness of the working face was raised from 200 to 500 Brinell and the service life appreciably extended.

Foundrymen called upon to produce sound castings in high-duty irons may find the following remarks of some assistance. Such irons, which are almost invariably of the low-carbon type exhibit an elevated freezing range, that is to say, solidification begins at a temperature appreciably higher than that at which it is complete. Over this range of temperature, therefore, crystals of solid metal exist in intimate conjunction with residual liquor. By reason of this characteristic, these irons are particularly subject to the defect known as "interdendritic shrinkage," which is generally evidenced as jagged cracks, often so small as to be invisible to the unaided eye. Such fissures are formed, during the process of solidification by the abstraction of liquor from around the primary crystals. (An excellent discourse on the mechanism of formation of defects of this nature, together with sound advice on methods for their prevention, has been provided by Timmins.)* Furthermore, since the amount of graphite finally present in such irons is relatively small, the total shrinkage which they exhibit is correspondingly great and more generous "feeding" than the normal is required.

Promoting Controlled Directional Solidification

The advised procedure is to design the moulding, gating and pouring arrangements so that controlled directional solidification is promoted. In other words, if steps are taken to ensure that solidification takes place progressively through the various sections of the casting, being completed in the riser or feeding head, sound castings can readily be produced. Generally, this aim can most definitely be realised by top pouring through small gates. Mr. Braidwood illustrated these remarks by blackboard sketches depicting good and bad production practice as applied to castings of simple type.

He could not permit himself to be drawn into public debate on the subject of high-duty cast irons produced by any of the patented processes. He was content simply to show that the highest existing specifications could be met by utilisation of the straightforward procedure which had been fully described.

MR. A. PHILLIPS said that one point of interest to him was in regard to the graphite arrangement in cast iron. Had Mr. Braidwood found that he could alter the graphite form by any other method than that of adding graphitisers to the ladle or to the metal? Had the rate of melting any influence on the structure when using a high percentage of steel in the charge? When making small castings in high-tensile iron it would seem to be preferable to use inoculated metal.

MR. BRAIDWOOD said he could give no information with regard to the influence on structure of variations in melting rate. The charges had all been melted under fairly constant conditions, and there were, therefore, no particular variations in melting rate observable. He had employed no method of altering the graphite form other than that which had been described. Mr. Phillips was quite correct in assuming that it was better to use an inoculated iron when pouring light section castings. With a properly inoculated iron of suitable composition there would have to be very rapid cooling indeed in order to produce a white or mottled structure.

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* B.C.I.R.A. Research Report No. 2063:—"A Theoretical Consideration of the Factors Affecting the Formation of Shrinkage Defects in Cast Iron," by A. A. Timmins, F.I.C.

A hearty vote of thanks was accorded to the lecturer on a proposal made by Mr. W. Holland, seconded by Mr. A. Phillips.

DISCUSSION

FALKIRK SECTION

MR. W. W. BLAIR asked Mr. Braidwood if inoculation would have any beneficial effect on high-phosphorus irons, such as were in use in the light-castings foundries of the area. He wondered if the lecturer had experienced any trouble due to high sulphur content in his irons.

MR. BRAIDWOOD said that, though inoculation was most necessary, and its influence most potent, in the case of low-carbon irons, he had found the procedure to be of benefit when applied to high-phosphorus irons of the commercial type also. At the present time he was obliged to pour miscellaneous castings in a 1.2 per cent. phosphorus iron, and trouble had been encountered in the form of "draws." Inoculation of the iron, by the simple process of floating lump electrode in each vessel, had brought about marked improvement in foundry results. [For a full account of this procedure see the report of the Lancashire Branch discussion.]

With high-steel charges, the sulphur pick-up on melting could be considerable, but, as would be seen from the tables, the final sulphur contents of the high-duty irons described were generally below 0.1 per cent., and were very often much lower. Phosphorus contents were, of course, very low, due to the nature of the charged materials.

MR. R. R. SHAW said that he was interested in Mr. Braidwood's contention that steel in the cupola melted as such. In what zone of the furnace did such melting take place? With regard to the higher impact values of the inoculated irons, were these entirely due to alterations in the form of the graphite? Was it not possible that the improved results were attributable, at least in part, to modification of the matrix?

Conditions in the Cupola

In reply to the first point, **MR. BRAIDWOOD** described in detail the ingenious experiments of those authorities to whom reference had been made in the Paper, and, with the aid of blackboard sketches, indicated his conception of the situation existing within the cupola during the melting of steel. He pointed out that such material must melt nearer to the zone of maximum temperature than did cast iron, and stressed the necessity for maintenance of an adequate bed. The improved impact values found to result from inoculation of the irons described were undoubtedly due entirely to the marked alterations effected in graphite form and mode of distribution. The respective sets of test-bars were uniformly pearlitic.

MR. T. TYRIE invited the lecturer to describe the types of castings normally poured in the high-duty irons described and to indicate those principles of gating, etc., which had been found most suitable. He was interested in Mr. Braidwood's technique of inserting extra coke charges at intervals, and he asked if this practice was recommended for all cases in which steel scrap formed a substantial part of the charge.

In reply, **MR. BRAIDWOOD** discussed the characteristic defects to which low-carbon irons were prone, and outlined the means by which these might be prevented. He emphasised that there was nothing in the production of high-duty iron castings to worry any go-ahead foundryman, who was prepared to adapt his technique intelligently. The essentials were the promotion of progressive directional solidification and the provision of adequate feeder heads. [For a more complete statement on production technique see the Lancashire Branch discussion.]

The insertion of extra coke charges at proper intervals was a practice which should be followed wherever appreciable proportions of steel scrap were incorporated in the cupola charge. At Renfrew, this was routine procedure in the daily, bulk production of good-quality irons, satisfying Specification 786, Grade 2, and prepared by the melting of pig and steel charges. If ordinary irons were required to follow, the provision of a generous coke layer on top of the ultimate steel-containing charge, was especially recommended. This had the effect of restoring the bed to normal height and also promoted sharp separation of the respective grades of iron.

WRITTEN CONTRIBUTIONS

MR. J. G. PEARCE wrote that this admirable Paper confirmed that any foundry with the will and the ability to exercise control in its operations can make high-duty cast irons, and the foundry doing so is indeed fortunate if it has available rust-free steel scrap of suitable section. In general, he could fully confirm the author's points, particularly those relating to melting practice, although the experience of the B.C.I.R.A. was that the stated manganese losses in briquette melting were on the high side. He found them roughly similar to those of silicon. He urged the author to specify the type of pyrometer he used and whether the figures were or were not corrected. Mr. Morrogh, in a parallel contribution, had dealt with the question of nomenclature of graphite and had made out a case against the use of the term "random" graphite. However randomly distributed it appears to be, it was preferably termed "normal," since the distribution was never really random. It was difficult to understand the author's objection to the use of the term "supercooled," or, as it was preferably called, "undercooled" graphite, which had been used by the B.C.I.R.A. since 1928. Advice to secure fine graphite referred, of course, to fine flake graphite and not to under-cooled graphite.

Since the B.C.I.R.A.'s recommendations regarding a single blow impact test, using a 0.875-in. cylindrical, machined, but unnotched bar were put forward in 1939, a good deal of work had been done with the object of using the 1.2-in. bar, which is probably in more general use than the 0.875 in. Unexpected difficulties had been met. Did the author experience a double or multiple blow on his impact bar, evidenced by marks below that of the original blow, and, if so, did he consider that the results were thereby affected? Did he consider the test in its present form sufficiently satisfactory to standardise?

While the present writer shared the author's admiration for much of the metallurgical work done in the United States, it may be appropriate to recall that in 1929 Norbury* showed that cast irons of identical compositions could have entirely different structures, one of normal and the other of under-cooled graphite. The under-cooled graphite iron was darker in colour and denser in structure, was softer and more machinable than normal graphite iron of the same composition. Frequently, at that time, both structures occurred in the one piece of metal and the mechanical properties of these mixed structure irons were inferior to those given by either structure exclusively. The under-cooled structure was shown to chill more readily and yet, when grey, to be associated in the final structure with ferrite rather than with pearlite. The structure found commercial application in Silal and Nicrosilal heat-resisting irons, and more recent work has shown its remarkable freedom from shrinkage and unsoundness in compositions which with normal graphite would be expected to show shrinkage. Undercooled-graphite irons made from the same pattern were invariably slightly smaller than normal graphite irons, and hence were slightly denser. There was a general tendency to condemn the undercooled graphite structure on the ground of its greater rigidity, poorer mechanical properties, poorer wear-resistance, *e.g.*, in brake drums, but an attitude of general condemnation was to be deprecated. In many cases, a compromise had to be made between the properties of castability, soundness and mechanical strength.

Undercooled Structure Long Known

The undercooled structure was not new in itself. It had been observed in old photomicrographs, was frequently found in commercial irons, and its formation was fostered by superheating or rapid cooling. Norbury pointed out the analogy between these normal and modified (undercooled) cast irons and the ordinary and modified aluminium-silicon alloys, and doubtless one explanation would serve for both. These alloys, incidentally, had to be undercooled in order to be modified, but undercooling did not necessarily result in modification. The eutectics containing undercooled graphite undoubtedly solidified at a lower temperature than the normal graphite eutectic and in a later Paper,† Norbury and Morgan dealt with the effect on graphite structure of the use of steel in the charge and of ferro-silicon and other ladle additions. The undercooled-graphite structure had been referred to above as "modified." There was some risk of confusion in the use of the term "modified" to treatment by ladle graphitisers, or inoculation. Up to 1936 no positive method of producing these structures throughout cast iron was known, for superheating and chilling were uncertain in their effects, but the now well-known titanium/carbon-dioxide process* evolved by the B.C.I.R.A. accomplished this, even in very heavy sections and from cupola-melted material, but its further development had been interrupted by the war.

Mechanism of Graphite Formation

Apart from any industrial use of these undercooled-graphite irons, the subject had considerable bearing on the mechanism of graphite formation. The graphite nucleus theory, so wholeheartedly embraced in some of the U.S. Papers referred to, had not been supported in this country to any extent since 1930. One could not argue that graphite dissolved readily at temperatures just above the liquidus and postulate a shower of graphite particles on adding an inoculant. Following the recognition of the ready solubility of graphite at molten metal temperatures, attention was drawn to the possible nucleating effect of non-metallic inclusions, although it was recognised that nucleation required the introduction of particles of similar crystal structure to those about to be precipitated. More recently, a good deal of work had been done on the determination of the nature and quantity of non-metallic inclusions, and a number of pig-irons had been examined by the B.C.I.R.A. by chemical methods for oxide inclusions. The amounts present were so small as to make them a very speculative basis for theory. Furthermore, Mr. Morrogh, as a result of exhaustive microscopic examination, had failed to find the presence in ordinary cast irons of oxides of iron, manganese or aluminium, or of the silicates which would be revealed by chemical methods as oxides. Thus, any inclusions must, if they were there at all, be sub-microscopic or be dissolved in the metallic matrix or in the admittedly more extensive sulphide inclusions. On the other hand, entrained slag, moulding sand or oxide resulting from overheating cast iron were readily seen under the microscope.

However, it was fortunate that practice did not need to wait for a full explanation of the obscure mechanism of graphite formation. The metallurgist required to be able to control the amount of undercooled or normal graphite, which was possible, as the Paper indicated, by the use of what the B.C.I.R.A. originally termed "inoculants," because the effect was so out of proportion to the quantity used. Many substances had now been tried for these purposes. The term had been widely used, both here and in the U.S.A., and had also been criticised, but no more suitable term had been suggested, although the word "nucleation" might prove to be satisfactory. The term "graphitiser" might be misleading, for the inoculant prevented the formation of undercooled graphite, and the accompanying disadvantages of the mixed structure, without appearing to influence the amount of distribution of the normal graphite. Any explanation of the effect of an inoculant must have regard to the fact that the structure of an inoculated iron was, any differences in composition being allowed for, not distinguishable from that of a non-inoculated iron. How could this be reconciled with the suggestion that in the one case a shower of graphite particles was produced? On the other hand, why should graphite-free scrap and charges be so desirable? The subject was packed with unanswered questions.

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* Journal, Iron and Steel Institute, 1929, I.

† Journal, Iron and Steel Institute, 1930, I.

* Journal, Iron and Steel Institute, 1936, II.

Terminology of Fine Graphite

MR. H. MORROGH wrote: The author had presented in this Paper information of both urgent practical and theoretical interest. He should be congratulated, firstly, as a foundryman and, secondly, for the extremely stimulating manner in which the results of his experiments had been presented.

The author discussed the terminology of fine graphite formed in grey cast iron by undercooling of the melt. This type of structure had been variously referred to as supercooled, dendritic, abnormal, eutectic and eutectiferous, as the author pointed out. Dismissing these terms as either being not strictly correct or actually misleading, the author substituted the word combination "grain-boundary-graphite," claiming that it was the most accurate description so far applied, and on account of the cumbrous nature of this preferred to use the term "reticular-graphite." It was a personal opinion that this term was no better than any of the others. In view of the fact that no satisfactory term for this type of structure existed, and since a large number of various terms were in use, which, like the author's, were either misleading or incorrect, it was worth while to examine the possibility of formulating a more accurate and disciplined terminology.

First, it was necessary to examine the mechanism of solidification of a grey cast iron. Ordinary commercial cast irons had a complex constitution, and strictly they must be considered at least as ternary or quaternary alloys. When a grey cast iron solidified the first solid phase to form was austenite, which was deposited from the melt in the form of dendrites. As solidification proceeded the melt reached a composition and temperature when it was simultaneously saturated with both austenite and graphite. These two phases were then deposited simultaneously in the form of a binary complex. Strictly speaking, it was incorrect to refer to this complex as a eutectic since the alloy was complex and the duplex structure might be formed over a range of temperatures, and over a range of composition, and furthermore it did not possess the lowest melting point of the constituents or phase combinations present in the solidified alloy. Normally the graphite of the binary complex was in the form of relatively large flakes or lamellæ, but undercooling could occur and then the graphite was formed in a very finely divided form. Thus far the significant facts arising from this discussion were that it was incorrect to use the term eutectic, although since the binary complex solidifies in a manner similar to that of a eutectic it was justifiable to use the term "eutectiferous." It is also seen that in an ordinary grey iron the graphite complex was formed after the primary austenite dendrites and were distributed around the dendrites. Thus the term dendritic was obviously incorrect, while the terms extra-dendritic and inter-dendritic quite correctly describe the structural position of graphite in cast iron of ordinary commercial compositions. However, neither of these terms differentiated normal long flake graphite and the fine graphite formed by undercooling. Both of these graphite forms were inter- or extra-dendritic, and in this sense they were both the same, that is, they were both formed after the austenite and around the dendrites.

Dendritic Structure

That ordinary flake graphite is inter-dendritic was a fact which was not generally appreciated or understood, and doubtless this misunderstanding had led to the conception of "random" graphite and "dendritic graphite." In low carbon irons, that is, irons with less than 2.7 per cent. carbon, both normal and undercooled structures showed graphite which was manifestly formed between dendrites. This clarity was due to the fact that the primary dendrites occupy a relatively large proportion of the total metallic matrix. In the case of the higher carbon (3 to 3.6 per cent.) commercial alloys, the binary complex occupied a very large part of the structure, and since the metallic phase of the binary complex was continuous with the primary dendrites in the transformed structure at room temperature the primary dendrites tended to become masked. By suitable etching technique, however, the primary dendrite structure could be revealed and the primary dendrites could be seen to have the graphite surrounding them. Boyles* had shown some very convincing micrographs of flake graphite forming between the primary dendrites.

A further factor contributed towards the mode of distribution of the graphite, and that was the pouring temperature. Norbury† had shown that the higher the pouring temperature of a given alloy the fewer and longer become the primary dendrites, the higher the pouring temperature the dendrites became more columnar. With lower pouring temperatures the primary dendrites increased in number and became more equiaxed. These were general laws applying to all alloys, including cast irons. Now it had already been shown that the graphite in cast iron, whether of the normal or undercooled variety, was positioned around the primary dendrites, and thus the form and size of the primary dendrites influenced the distribution of the graphite. (It was important to note that it was the distribution of the graphite and not the size of the graphite flakes which was the present concern.) It followed that the pouring temperature would also affect the mode of distribution of the graphite. With high pouring temperatures when the dendrites were few and long the graphite tended to be arranged in definite planes following the arms of the primary dendrites. With low pouring temperatures when the dendrites were more equiaxed the graphite tended to assume a more random arrangement, but the distribution of the graphite was still determined by the primary dendrites.

Effect of Pouring Temperature

This effect of pouring temperature was most marked in low carbon irons, where the proportion of primary dendrite in the microstructure was high. The effect was least marked in high carbon irons where the proportion of primary dendrite in the microstructure was low. Thus for all irons the tendency to give random distribution of graphite was most marked with low pouring temperatures. Pouring temperature was, of course, a purely relative expression, and low pouring temperature really meant a small temperature interval between the pouring temperature and the freezing point of the alloy. A high pouring temperature for a high carbon cast iron might be a low pouring temperature for a low carbon alloy.

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* Transactions, A.F.A., 1938, Vol. 46, p. 297.

† Journal, Iron and Steel Institute, 1939, II, p. 161.

The fine undercooled graphite followed the outlines of the dendrites in exactly the same manner, but the primary dendrites tended to be more obvious, because the metallic phase of the binary complex was more finely dispersed and was thus clearly distinguished from the primary dendrites. It followed from this that the only fundamental difference between the two types of graphite under consideration was the temperature of freezing or the extent of undercooling. From this it then followed that the only suitable term for the very finely dispersed graphite was "undercooled" graphite, and for the coarse form "normal" graphite. The term "normal" was used here to indicate the fact that the iron had solidified according to the ordinary conditions of stable equilibrium and that no undercooling had occurred.

From the foregoing it was seen that the author's term "reticular" (that is, resembling a net) was by no means an accurate description of the mode of distribution of the undercooled variety of graphite. The constituents which solidified after the binary complex certainly were reticulated, hence the term "phosphide network," but this applied to both normal and undercooled structures. The phosphide eutectic was always present in the form of a network in ordinary grey cast iron, regardless of whether undercooling occurred or not. This was because the binary complex solidified with spheroidal crystallisation front, and the lower melting point constituents were pushed towards the interstices of these binary complex spheroids. This spheroidal form of crystallisation characterised all binary eutectics and binary complexes irrespective of undercooling. Thus it was seen that the phosphide eutectic is distributed in the form of a net and not the binary complex. The binary complex merely filled in the interstices of the primary dendrites.

Cause of Graphite Distribution

Following the argument showing that since normal flake graphite was arranged around the primary dendrites, and since the distribution of the primary dendrites was a function of pouring temperature, it was interesting to observe that ladle inoculation was not responsible for the so-called random arrangement of graphite. Ladle inoculation with calcium silicide, ferro-silicon and electrode carbon prevented the formation of undercooled graphite, but in no way determined the mode of distribution of the normal graphite formed by this treatment. The final controlling factor deciding the distribution of this graphite was the pouring temperature. The higher the pouring temperature the weaker the iron tended to become, due to the formation of a pronounced and regular graphite pattern following the outlines of the primary dendrites. With lower pouring temperatures as the dendrites become more equiaxed, the graphite flakes tended to assume a more random type of arrangement. However, the arrangement was never truly random, and it was governed entirely by the distribution of the primary dendrites, and hence by the pouring temperature. It follows from this that, if a random graphite pattern was considered to be a criterion of good mechanical properties, then the aim should be to cast the metal at the lowest temperature consistent with being able to run the casting and avoid blowholes.

From the appearance of the graphite structures illustrated by Mr. Braidwood, it would seem that his test-bars had been poured with a very small temperature interval between the pouring temperature and the freezing point of the iron. Thus the flake graphite in the inoculated irons tended to assume a random distribution. In the case of his irons with undercooled structures, as a result of relatively low pouring temperatures, the dendrites were small and equiaxed, and in the particular cases quoted by the investigator presented a reticulated appearance. The real danger in the use of the term reticular rested in the fact that all undercooled structures might be thought to be distributed in this manner. Actually, with higher pouring temperatures, the reticular pattern disappeared and the graphite became manifestly inter-dendritic.

The term "reticular" defined the appearance of the structure rather than the mode of formation of the structure. When appearances were concerned, it was well to consider the relationship between the polished surface of the microspecimen and the three-dimensional distribution of the constituents. For instance, a certain spot in a microspecimen must have a reticular appearance because the surface of the microspecimen cuts the arms of the primary dendrites. In this context it was always advisable to examine these graphite structures at the lowest power possible, in order to appreciate the extra-dendritic pattern of the graphite.

It is interesting to note here that an inoculated iron was not essentially different from an ordinary cast iron. It was not possible to view an iron under the microscope, and to say "this iron has been inoculated." As far as the structure was concerned, inoculation merely guaranteed the absence of undercooled structures.

Eash's Theory

It was somewhat disconcerting to find that the author appeared to have accepted unconditionally the conclusions drawn by Eash from his experimental work. The work carried out by Eash was excellent, and his theory, which was apparently backed by irrefutable experimental work, that undercooled graphite was formed by the decomposition of white iron and that normal flake graphite was formed directly from the liquid, was extremely fascinating, but before it was completely accepted, certain known facts needed lining up with this theory. It appeared that Eash had completely overlooked a few details which, if not disproving his theory, certainly needed much imaginative explanation in terms of this theory, or which tended to restrict his explanations to the castings made under the isolated conditions of his experiments.

First, it is a well-known fact that it was possible to produce either normal or undercooled graphite structures in high-silicon irons. It was well known that 4 to 6 per cent. silicon irons of the Silal type when correctly made had an undercooled structure. Further, undercooled structures could also be obtained at will in the corrosion-resisting irons of the 10 to 15 per cent. silicon class. Are metallurgists to assume that undercooling in these irons with 5 to 15 per cent. silicon occurred according to a different mechanism from that in the lower silicon irons, or were they to assume that iron carbide formed even though momentarily in an iron containing 15 per cent. silicon? If iron carbide was an essential intermediate between the melt and the undercooled graphite structure it would be expected that undercooled structures would be more difficult to realise in high-silicon irons.

Secondly, it had been shown that by treating the metal with titanium and carbon dioxide it is possible to produce undercooled structures in 3 to 3.5 per cent. carbon and 1 to 3 per cent. silicon irons of 6-in. section and more. Again, had one to assume the momentary stability of iron carbide at temperatures and with cooling rates and compositions of such an order that even the momentary stability of iron carbide became questionable?

Undercooled Structures and Mechanical Properties

It seems strange that the author found that the presence or absence of undercooled structures exerted no dominant influence upon the mechanical properties with the exception of resistance to impact. In personal experience, the presence of an undercooled structure produced low mechanical strengths all round. One of the reasons why ladle inoculation gave improvements in tensile and transverse strength was the removal of the undercooled structure. However, since undercooled structures tended to give poorer mechanical properties it should not be thought that irons having these structures could be dispensed with entirely. It had been clearly shown that heat-resisting irons, such as Silal and Nicrosilal, resisted oxidation more efficiently when the graphite was in the undercooled form. Furthermore, in making a casting it was sometimes necessary to compromise between good mechanical properties, soundness, that is freedom from porosity, and uniformity of structure throughout a given section. For instance, at the B.C.I.R.A., the staff had to make some solid blocks measuring 8 by 5 by 7½ in., and it was essential that the castings should have fairly good mechanical properties, and at the same time show absolute freedom from porosity at the centre of the blocks. In order to achieve this the blocks were made in an alloyed iron.

The presence of nickel and molybdenum guaranteed fairly good mechanical properties. The molten metal was treated with titanium and carbon dioxide to give castings containing a wholly undercooled structure. The resultant blocks were absolutely free from internal porosity and were of uniform hardness. The Brinell hardness numbers obtained across a section cut from the centre of a trial block were (from edge to centre) 205, 201, 197, 203, 197, and 201.

AUTHOR'S REPLY

Mr. Braidwood wrote that the communication from the British Cast Iron Reseach Association was a greatly appreciated contribution to the discussion of his Paper. His reply should begin with a justification of the choice of the term "reticular" to describe graphite of the characteristically arranged, fine-flake type which questioners preferred to call "undercooled" graphite. The several alternative terms, in descending order of dislike, are dealt with below:—

"*Eutectic*" *Graphite.*—This description would apply to graphite precipitated from the liquid as a constituent of a eutectic. Therefore, graphite of the type under discussion, which was evidently formed from the solid, had no claim to this title. Actually, "eutectic" graphite was graphite of the normal flake type such as was present in ordinary grey irons, and the use of this term to identify graphite of the type under discussion was positively misleading. This has been stressed by Eash.*

"*Eutectiform*" *Graphite.*—This meant "having the appearance or form of a eutectic," and, as had been pointed out by Flinn and Reese,† this term was vague and might even be confusing by reason of the many known forms of eutectic structure.

"*Dendritic*" *Graphite.*—As Mr. Morrogh has himself indicated, this description was quite incorrect. Where graphite of the type under discussion was present, it was the matrix that was dendritic, not the graphite. "Inter-dendritic" or "extra-dendritic" were the terms really justified.

"*Abnormal*" *Graphite.*—Personally reported experiences had shown that graphite of the type under discussion was not abnormal in low-carbon irons; on the contrary, it was precisely that form of graphite which would almost invariably be present unless special measures were adopted to ensure its absence. In low-carbon irons, therefore, such graphite was actually the normally-occurring type and the proposed term became dangerously indefinite.

"*Supercooled*" *or* "*Undercooled*" *Graphite.*—Strictly speaking, it was not the graphite that was undercooled, but the metal from which such graphite was subsequently liberated. The term, therefore, was not precise. It might be argued, of course, that, since undercooling was observed to be associated with the formation of such graphite, there was justification for the use of this term. It would not be correct, however, to assume that such graphite was produced because the metal had experienced undercooling. It was very probable that undercooling of the melt and formation of this fine graphite were mutually the result of the operation of some other factor, for example, the absence of nuclei.

"Reticular" Graphite Justified

What objection was there to the use of the term "reticular" graphite? Mr. Morrogh stated, incorrectly:—"The term 'reticular' defined the appearance of the structure rather than the mode of formation of the structure." That really should have read:—"The term 'reticular' defined the appearance of the graphite distribution rather than the mode of formation of the graphite." Precisely! And that, at the present time, was its chief virtue. When, at last, some single theory of graphite formation was proved completely and accepted universally, technically-perfect terminology might be framed by common consent. Meanwhile, and so long as metallurgists continued in the midst of an almost bewildering whirl of theories and counter-theories, it was surely wise to avoid all reference to assumed modes of formation and use terms descriptive of appearance only, yet sufficiently definite to make clear distinctions possible. The term "reticular graphite" can be so classified. (The writer does not claim to have coined this term; it was used several years ago by Dr. Nipper,* or his translator.)

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* A.F.A. Preprint No. 41-9, p. 16.

† A.F.A. Preprint No. 41-14, p. 9.

Since all graphite in grey iron was in the form of flakes, whatever their distribution or relative size, the unsupported term "flake" graphite was inadequate. Similarly, and for reasons already listed, the description "normal" graphite was not sufficiently definite. Objection to the use of this term, however, was mild, as was evidenced by its frequent appearance, for the sake of variety, in the Paper.

Inter-dendritic Arrangement of Graphite

Mr. Morrogh declared that all graphite flakes were in inter-dendritic arrangement, and claimed that this could be proved by microscopical examination of suitably-etched specimens. This information was welcomed, since personal inability to trace inter-dendritic distribution in adequately inoculated low-carbon irons very much puzzled the author. In such irons the dendrites of austenite must be present in considerable proportion at the instant of solidification of the eutectic liquor, and the graphite should be located in the interstices. The micrographs, however, gave little evidence of such distribution.

He was perfectly ready, nevertheless, to accept Mr. Morrogh's assurance that by suitable etching and more expert interpretation, inter-dendritic distribution of graphite could be confirmed microscopically in all cast irons, and he considered that Mr. Morrogh had made out a good case against any use of the terms "grain-boundary," "inter-dendritic" or "extra-dendritic" graphite. When, however, he asserted that, since the distribution of his "normal" graphite was really inter-dendritic, the use of the term "random" graphite was unjustified, the writer could not agree. Concentrate only on the description of appearance and "random" graphite was seen to be an eminently fitting title.

The Eash Research

The recent Paper by Eash was, from a personal point of view, a first-class contribution to contemporary metallurgical research, and that author's deductions provided a simple working hypothesis which served to explain personal observations. It was not correct, however, to assume that the author had "accepted unconditionally" the conclusions drawn by this investigator. It was difficult to conceive of the existence of undissolved particles of graphite in an unsaturated melt. Nevertheless, it must be remembered that the equilibrium solubility was not the only factor which operated in practice, and there was much evidence to support the postulated existence of graphite nuclei. If undissolved particles of graphite were indeed present in the melt, increase in temperature or maintenance at constant high temperature should each promote solution. By experiment it was found that those effects which could logically be attributed to the presence of graphite nuclei did actually diminish on superheating of the melt, or on holding at constant high temperature. That was circumstantial evidence only, but there was more positive proof available.

In their recent Paper,* Massari and Lindsay reproduced micrographs of the structure of quenched droplets of hypo-eutectic irons. At high magnification these reveal the presence of graphite nuclei, and the authors demonstrated that the graphitising behaviour of any of the irons examined is proportional to the concentration of nuclei found in such specimens. It might, of course, be argued that even evidence such as this was not absolute, since, in the short period of time required for quenching of these droplets, tiny particles of graphite might be precipitated.

Yet even such scepticism did not render the nuclear theory untenable. In his contribution† to the discussion of a Paper by Norbury and Morgan Dr. Desch stated that:—". . . there was a good deal of evidence to show that in a molten alloy of iron and carbon, there were present molecular groupings which corresponded with iron, with iron carbide and with graphite. Those molecular groupings would be destroyed as the temperature was raised. In inorganic chemistry there were many examples of that survival up to a certain point and gradual vanishing with superheating, and it seemed that those molecular groupings which had not yet reached the stage of having crystallised out of solution did furnish the requisite nuclei."

It appeared, therefore, that the nuclear theory, to which Eash and most of his transatlantic contemporaries subscribed, could be very strongly supported indeed.

Eash's Graphite Conclusion Accepted

Of the correctness of Eash's conclusion that graphite of the fine, reticular type was formed in the solid while random flake graphite was precipitated from the liquid, he had no doubt whatever. Surely, it was this fundamental difference which produced the striking disparity in the size of the respective individual flakes and which caused grey irons with reticular graphite to be more dense and to exhibit greater contraction than irons of similar analysis containing random flake graphite.

It is also his conviction that in irons of the type used by Eash, as well as in irons such as were described in the Paper, graphite of the fine, reticular variety was formed by the breakdown of meta-stable carbide. It was certainly doubtful, however, that carbide would be formed, even momentarily, in high-silicon irons such as were quoted by Mr. Morrogh, and there was possibly a very real need for a series of quenching experiments on irons of this type, on the lines of the procedure so successfully developed by Eash. Might not this be a line of research which could profitably be undertaken by the Association?

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* "Graphite Formation and Structure in Cast Iron." H. Nipper, Proceedings I.B.F., Vol. XXVII.

* "Some Factors Influencing the Graphitising Behaviour of Cast Iron." Massari and Lindsay, A.F.A. Preprint No. 41-7.

† Journal, Iron and Steel Institute, 1936, I, p. 347.

He (the author) fully realised that his findings with regard to the tensile strengths of those irons containing reticular graphite were not in agreement with expectation nor with the reports of other investigators. It did seem illogical that a structure offering poor resistance to impact should possess high strength in tension, but the same phenomenal behaviour was exhibited by temper-brittle steels. These might have excellent tensile strengths and elongation values, yet fail wretchedly under impact. He entirely agreed with Mr. Morrogh that inoculation simply ensured the absence of reticular graphite and did not produce any exclusively characteristic effect upon the micro-structure.

From examination of the micro-structures featured in the Paper, Mr. Morrogh had deduced that the test-bars were poured at rather low temperatures. Actually, this was not the case, the aim throughout being to pour each bar at an observed temperature of approximately 1,300 deg. C. Maintenance of this pouring temperature, which represented fairly hot metal, ensured adequate fluidity and standard pouring conditions in all instances. It was possible, however, that the use of a long narrow ingate (see Fig. 2 of the Paper), designed to give slow pouring and appreciable temperature drop between basin and mould, had been responsible for the effects noted by Mr. Morrogh. All of the temperatures quoted were uncorrected readings made on a Cambridge optical pyrometer of the disappearing filament type.

Impact Testing

The single-blow impact test, conducted as recommended by the Association, had proved to be both reliable and informative; indeed, the main finding of the Paper was based upon the information which this test had afforded. Almost invariably there were two indentations in the detached portion of the specimen. These were located on the near face, one directly above the other and about 1 in. apart. The upper was the groove resulting from the impingement of the hammer; the lower was a smaller impression evidently caused by the bouncing of the detached portion against the rear of the hammer. Markings on the flat upper surface of the vice and a corresponding dent on the top, far rim of each specimen, confirmed this verdict.

It was of interest to record that no secondary impression was found on specimens of the austenitic irons which were relatively ductile and possessed of high resistance to impact. The top portions of such specimens, apparently, did not break off so sharply and did not bounce with sufficient rapidity to make contact with the outswinging hammer. Formation of the secondary indentation did not appear to affect the reliability of the results obtained. A determination of reproducibility of results, conducted at the outset by the breaking of several identical specimens, gave very concordant figures, and all duplicate tests yielded values which were in close agreement.

In its present form the test was of very real worth. It would be an advantage, however, if the values generally obtained were greater, and less cramped toward the lower end of the standard Izod scale. Improvements, therefore, would probably follow from increase in the cross-sectional area of the specimen or from reduction of the striking height. Moreover, since the absolute accuracy of the result must be affected, however slightly, by the formation of the secondary indentation, some preventive adjustment was necessary before the test procedure can be recommended for standardisation. It was probable that alteration of the upper surface of the vice, from a flat to a sloping face, might achieve this object.

For the unwitting failure to acknowledge the notable exploratory work carried out by the Association, and particularly by Dr. Norbury, due apologies are tendered. The complimentary references made by both correspondents to the practical value of the Paper are much appreciated.

MR. W. Y. BUCHANAN also wrote: I have found Mr. Braidwood's Paper, "Cupola-Melted High-Duty Cast Iron," particularly interesting, and would like to make a few observations on the lines indicated during the discussion on its presentation to the Scottish Branch.

With reference to his ladle "inoculation" with carbon, I first tried this as a means of increasing the carbon content in connection with the melting of borings, where the carbon content could be brought very low, *i.e.*, sometimes lower than there was any demand for.

From this work, which is referred to in a Paper to the Falkirk Section, January, 1940, I concluded that in fact the quantity absorbed in the metal had an effect out of all proportion to its magnitude, at least so far as fluidity was concerned.

The following statement also appears therein: "Much practical experimenting could be usefully carried out as to its effect on structure, which on preliminary test does not seem very marked, although the additional dissolved graphite seems to be of small size; about two-thousandths of an inch in length."

This Paper, of course, referred to cast iron which never shows other than random graphite.

Tensile and transverse tests were taken as a matter of routine in addition to the fluidity tests, but no change in this was observed as a result of the graphite addition.

The graphite used was in flake form and had an absorption of about 50 per cent. Perhaps Mr. Braidwood could check the effect of his treatment on fluidity, as the fluidity of this class of metal often determines the freedom or otherwise from defects due to dissolved gases, a practical aspect of the making of high-duty iron castings which cannot be ignored unless in very simple designs.

Impact tests were not carried out, and so the important conclusion arrived at by Mr. Braidwood was missed. This seems to emphasise his contention that impact tests should be made as regularly as tensile tests.

In reply to Mr. Buchanan, the AUTHOR wrote: Mr. Buchanan's interest in my Paper is most gratifying, and his communication is welcomed. The high-duty irons produced as described, "inoculated" or otherwise, are very readily castable, and it is probably for that reason that the determination of relative fluidity values has not so far been contemplated. It should not be difficult, however, to conduct such tests in order to assess the practical influence of "inoculation" on the fluidity of these irons, and the findings might well inspire a short article of some interest. If Mr. Buchanan could let me have the use of his patterns, etc., the progress of the proposed investigation would be greatly expedited.

Salvage and Disposal of Foundry Waste

By Wm. Y. BUCHANAN (Member)

In elementary chemistry it is an axiom that matter is indestructible; in short, even during combustion the materials burnt merely change their form. With this thought in mind one is apt to find many so-called waste materials capable of further use, although of course the market values usually have the casting vote in the matter.

Market values fluctuate from time to time sometimes with good reason and often without, and the value of recovered materials is therefore a question which must be considered periodically. Salvage must be considered as distinct from disposal, and salvage at present is very much a matter of public discussion.

In considering the subject of salvage it is rather difficult to draw a dividing line between salvage and economy. For example, a more economic use of a material may be said to result in the salvage of what was previously wasted. However, for the present it is proposed to adhere to what is strictly salvage, and take those departments of the foundry which have materials to dispose of and see how far it is possible to use these, taking the writer's own experience as a basis for discussion.

The waste materials likely to be worth consideration may be listed under the following headings:—

Melting.—Coke and metal from drop; coke breeze and small coke from bins; material from roofs and dust catchers; slag; firebricks.

Sand Plant.—Metal from oversize delivery; silt; material recovered by magnetic separation.

Dressing.—Core sand and moulding sand; core wires, grids, small iron and sprigs; dust from grinders, etc.

Drying Plant.—Clinker and ashes from stoves and portable driers; coal ashes from ladles.

Moulding.—Lifters and hangers, etc. (C.I. or M.S.); recovery of oil-sand cores.

Machine Shop.—Cast iron and steel borings; abrasive wheels.

Melting

Coke and Metal from Drop.—There are machines on the market for wet grinding the cupola drop, in which the object is to grind up all but the metal, and this is washed clean with a continuous stream of circulated water. The machines consist of a steel barrel resembling a rumbler in which a heavy cylinder of metal rolls over the material to be treated. If this were made continuous in operation, it would no doubt be simple to work and show a good profit.

To separate coke, however, the only available method is hand-picking, by which coke and metal can be recovered separately. The coke thus recovered is used for its primary purpose principally in the cupola remelting recovered metal. The iron recovered is, of course, to a large extent mixed with slag, and advantage is taken of this to ensure a large slag volume in the remelting process; indeed, slag is often added to the charge to make up any temporary deficiency.

Coke breeze gradually accumulates in bins, where coke is unloaded out of a truck and the loading done at the outside edge of the heap. There seems little application for this unless in specially designed firing units. It may, however, be used as a hot-top cover for large feeding heads with or without gentle air blast.

Coke too small for cupola melting, but over, say, ½ in. size, can usefully be used in mould driers and small heating units, where it is more efficient than the class of material known as gas-works char, giving more heat and less ash.

The material from roofs and cupola dust catchers, as would be expected, contains coke, limestone and iron, and probably sand or slag. This material, if left any length of time, rusts together into a hard cake which, to say the least, is difficult to remove from roofs.

The percentage composition of this material is:—

	Per cent.
Metallic iron	35.11
Silica	35.28
Iron oxide and alumina	45.54
Lime	0.30
Loss on ignition (coke and CO_2)	11.75

The quantity of this material produced annually must be quite considerable, and it is suggested that if placed aside to weather it would gradually form a miniature ore bed which in time would be worth lifting. The usual tendency to scatter it throughout other foundry refuse makes it quite worthless. The usual figure of 5 per cent. loss in melting in the cupola must represent a very large tonnage annually in this country, and any definite reduction would relieve the heavy demands on the imported raw materials.

Slag Losses

Slag.—With slag-skimming practice on a continuous running system, the loss of metallic iron is nil, and the percentage of iron combined in the slag as a silicate of iron should be kept at a minimum figure by regular daily analysis. The possible application of slag by its reuse does not seem very promising. The percentage of iron may warrant smelting at some future date. In poor cupola practice, no doubt the high percentage of metallic and combined iron will justify this, but where it is kept below 6 per cent., this is out of the question at present.

If graded or granulated, it can be used successfully for making concrete, but will not be able to compete with whinstone from a conveniently situated quarry. Another application of slag is the making of slag wool. The author has always maintained that the old steel-making axiom, "if the slag is right the metal is right," applies more or less to the cupola also. Using ample limestone (the average practice invariably uses too little) and generous addition of fused soda ash, a very fluid basic slag is produced.

This can be collected in a ladle and poured at relatively long intervals in a selected spot. Slag in this condition can readily be converted into slag wool by a simple jet of compressed air. A makeshift demonstration can readily be arranged.

This material must have many applications, such as all forms of insulation, for example, houses, refrigerators, shipping and vehicles operating in low-temperature atmospheres. It should also be suitable for weaving cloth or sacking and heavy mats for various purposes, such as temporary coverings, etc., in military field operation, owing to its permanence in damp conditions which usually rot all sorts of vegetable fibres. The 45-in. cupola, melting for 2 hrs. daily, should produce several hundredweights of this slag wool, which can be sorted, if necessary, at the factory where it is finally used.

Firebricks.—Refuse firebricks may be used for concrete or ground and graded for core vent filling, and in some cases wet ground to form loam for special applications.

Sand Plant

Metal from Oversize Delivery.—The material from the oversized delivery of the sand-treatment plant consists of lumps of dry sand and cores mixed with cast iron and steel material in the form of sprigs, wires, fins, etc. Before remelting, this material is best treated magnetically to separate the metal, and there are various forms of machines incorporating magnetic pulleys and similar devices.

An attempt was made to adapt the sand plant temporarily to deal with accumulated oversize material by putting it through the sand plant in such a way as to miss the rotary screen and fall direct on to the rubber band conveyor going round the magnetic pulley. The magnetic material was then deflected from the pulley on to the floor and removed for remelting.

This arrangement dealt with materials at the rate of several tons per hour, but, owing to the position of this magnetic pulley in a rather confined space, and due to the wear and tear on the rubber band, the practice was discontinued and a separate magnetic pulley separator installed. This is fed from an overhead hopper and handles easily all the available oversize material from the sand plant. The magnet

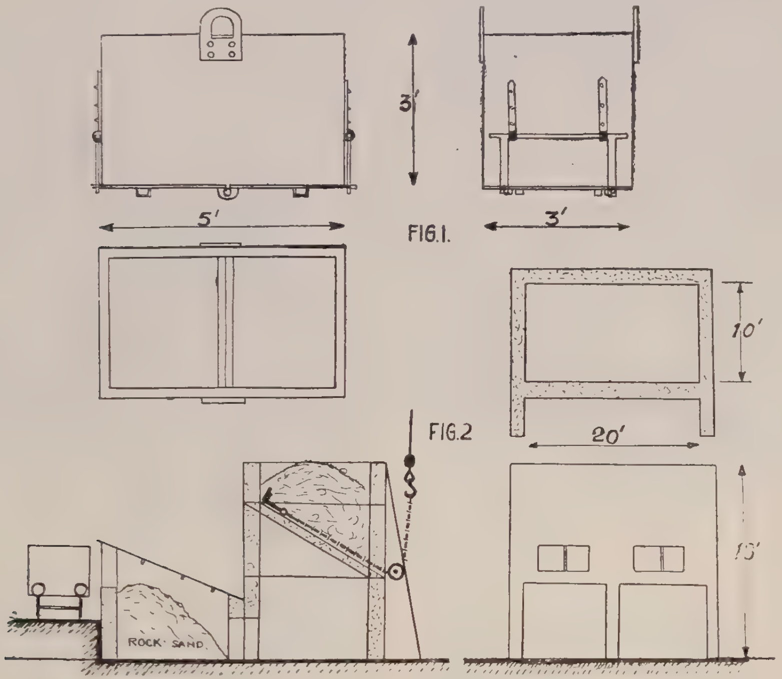

FIG. 1.—DESIGN OF BOX SHOWING THE BOTTOM HINGED IN HALVES FOR RELEASING THE MATERIAL.

FIG. 2.—GENERAL ARRANGEMENT OF THE ELEVATED REFUSE BIN AND THE SIMPLIFIED METHOD OF EMPTYING RAPIDLY.

should be placed before the oversize riddle.

Silt.—This material appears to have roughly the same composition as moulding sand, that is, the same percentage of clay and sand except that this is of a much finer grain size. There does not seem to be any moulding application except remixing in milled sand to control permeability and give a closer mould surface.

Small Metal from Sand.—The small metal from moulding sand passing $\frac{3}{8}$-in. riddle varies only in size from that recovered from the oversized material, and can be remelted in the same way.

Dressing

Core Sand and Moulding Sand.—The accumulation of material in the dressing shop contains large quantities of moulding sand more or less diluted with burnt oil-sand and this is returned to the sand plant for rebonding. The success of this may be limited in some ways, but mainly by the fact that, if less material is removed than that which is brought in, in the way of new oil-sand, the floor level begins to grow to a troublesome height.

Unburnt oil-sand or burnt oil-sand, which can be separated, may be reclaimed by suitable milling and sieving. This reclaimed material can be used up to 50 per cent. without trouble, and probably nearly 100 per cent. with care. The saving here is twofold: reduction in cost of new sand and reduction in cartage of refuse. The author has a small mill in operation which grinds and sieves old cores, but this design requires some further improvement, since it grinds very much faster than it sieves.

Core Sand and Moulding Sand. — The excellent Paper* by Mr. F. Hudson, "The Reclamation of Oil-Sand Cores," gives this particular field very careful consideration. It begins with a number of considered opinions of well-known men in the American industry on the subject, and the perusal of this confirms the general attitude here, namely, that there is often little to encourage expensive equipment installations in many cases where new sand is cheap, the quantity used is low, the work lends itself to dry sand or even green sand, and the disposal problem does not exist.

In the present author's experience this sand recovery has by change of incidental expenses become alternately an economical proposition, then uneconomical, then economical again. Many of the American authorities quoted in Hudson's Paper state that the recovery of oil-sand for making cores is not a practical proposition, although a few state that the recovered sand can be rebonded for moulding sand. The proposition of the problem is still the same at the present time, and its solution is the same also.

Several recovery methods are mentioned by Hudson, but the most popular seems to be the preliminary grinding and then sieving on screen about, say, 80 mesh, with, of course, a magneting operation as required. The sand so recovered from cast-iron castings is coated with a carbonaceous or oil deposit, according to the extent of burning of the core oil during baking, and this is shown to have a considerable effect on the gas generated in the core during casting the second time. It is evidently not considered economical to remove the coating by washing or rumbling.

The necessity for keeping this aspect in mind is obvious, but the economic aspect of the question makes it necessary to seek the simplest process. If recovered oil-sand be stored in the open it tends to disintegrate by the action of rain, but a well-baked oil-sand softens at a surprisingly slow rate, and, having once soaked up water, the subsequent sieving action is very difficult.

The present author's method is to employ one labourer collecting used oil-sand in a shed outside the foundry. The machine used is a type of pan mill. The cores are broken with a light plying hammer and thrown in the mill, from which only material less than $\frac{1}{8}$ in. mesh is delivered in a continuous stream.

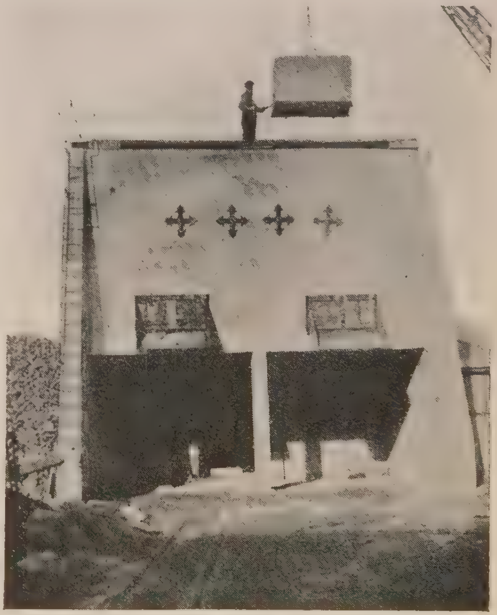

FIG. 3.—BOX OF GRANULATED SLAG BEING DUMPED INTO THE HOPPER.

The same operator removes the sieved sand to the Rotoil remixing plant. While the presence of the gas-forming material in the recovered sand is admitted, nevertheles this sand is regularly used by the author with 50 per cent. new sand, and only at 100 per cent. old sand did the cores scab or blow to a serious extent.

Core Wires, Grids, Small Iron Sprigs.—These may be made of special shapes, and should be recovered for re-use where possible. It is possible to straighten these for at least a few times, but after the steel has been subjected to the heat of casting, often enough it becomes crystalline and brittle. There is at least one machine for straightening wires on the market. The grids, fins, and small iron will find its way into the sand plant and be dealt with there. There has evidently been no attempt to design a machine to straighten and clean sprigs.

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* Foundry Trade Journal July 24, 1930.

Dust from Grinders, etc.—The dust-extraction plant serving the grinders, rumbling barrels, and airless shot-blast machines collects a fair quantity of material which contains a considerable percentage of iron, as shown by the following analysis:—

	Per cent.
Metallic iron	44.69
Silica	30.43
Iron oxide; alumina	69.04
Lime	nil
Loss on ignition	nil

This material may have some use in its original form, as, for example, in the making of exothermic powders for oxidation reactions, but, if not, it can be weathered into lumps in the open, when it should form a fairly good ore at some future date, provided that it is allowed to collect to a reasonable quantity, thus making it worth while arranging for its removal.

Drying Plant

The ashes or clinker from stoves and mould driers, if of the hard, clean type, can, of course, be used in ash beds, core vent, etc., so long as unburnt coal is carefully excluded. Unburnt coal, such as anthracite used in forced-draft fires, finds its way into sand and causes small gas holes at the mould face.

Where coal is used for drying ladles, a great deal of the coal is not burnt at all, and at the same time the bulk of the heat is lost. This coal, if unburnt, does not find a ready application, as it is often at present of a very inferior quality and becomes solely a disposal problem. Specially-constructed coke driers or oil burners with forced draft would dry the ladle much more satisfactorily and eliminate the disposal of ash.

Moulding

Where cast-iron hangers and grids are used, a considerable amount of work is necessary for making the daily requirements, as a large flat top part may use up scores, which, on the knock-out operation, are broken off. Then, again, if a short straight iron is required, there is a tendency to lift the nearest hanger and break it down to the required size. The recovery of cast-iron hangers for re-use is therefore rather poor.

As an alternative, mild steel has been used for these articles. There is, then, no need to wait for a supply of liquid cast iron to cast the required sizes. Further, the mild-steel hanger cannot be broken, and is therefore available for re-use a great number of times. The knock-out time in the case of a large top-part reinforced with mild-steel hangers is considerably increased, and this point should be borne in mind when considering whether it is worth while or not in ordinary times when materials are not restricted to the same extent as at present.

Final Disposal of Refuse

The author cannot recall ever having heard this subject discussed at any of the Institute meetings, but it is nevertheless a matter which cannot be ignored. In large or medium-sized foundries it may well amount to an important annual cost. In general, the refuse is a mixture of small and lumpy material which requires a flat surface from which to shovel. When tipped from barrows, it seldom rises above 2 ft. high, and thus takes up a considerable ground space. If a raised plank is used to run the barrow up to any height greater than 2 ft., a long flat run must be used, or the going is very heavy.

The mixed material then packs more heavily and makes shovelling more difficult still. It is common to have to loosen the material with a heavy pick before shovelling. Really good carters can shovel upwards into a cart or lorry, but, unless they are really good (and they very often are not), the work becomes tedious, and the periods of rest are apt to exceed the periods of active work. When outside men are employed continuously on this job, their work becomes gradually less enthusiastic, especially if employed at an hourly rate.

Cupola slag, if caught up in lumps from the floor and dumped from a barrow, is heavy, hard, ragged and awkward to handle, and, when mixed or buried in moulding sand, is very difficult to remove.

Many small foundries have a working arrangement to have rubbish removed by horse and cart at a fixed rate per ton. This method works very well so long as the carter comes to the foundry when required. However, this method may be too slow, and a self-tipping motor lorry is the next substitute. These can be hired with a driver at rates about 8s. per hr., but this rate will no doubt vary according to local supply and demand.

Flat or fixed trucks are unsuitable, as the refuse has to be shovelled off at the dumping point. By carefully placing the truck with relation to the heap it is possible to put several men to work filling by shovel, but unless the lorry can be so placed that it is surrounded on three sides by the waste material, not more than three men can work without getting in each other's way. Then when the lorry is on the way to the dumps the additional men are idle, and in the end it does not work out much better than carting.

Some people claim that carting is actually cheaper. Where motor vehicles are hired by the hour some supervision is necessary, or the nature of the work will bring about a diminishing work speed which makes removal very costly. Personal experience verifies this. In working on this refuse men show a tendency to move about selecting light unbonded material such as riddle ashes, sharp sand and the like, and often avoiding accumulations of slag.

It was felt that although the mixed nature of the material caused much of the difficulty, *i.e.*, in driving the shovel into the heap, the main cause of the tiring work was the lifting of this material to a height of some 5 ft. from the ground. Thus the best way to get at the solution of the problem seemed to be to arrange for the elevation of the material into an overhead hopper.

Overhead Hopper for Refuse Disposal

The author can only recall seeing one illustration of such a scheme in published literature, and as far as he can remember it consisted of a circular water tank on four legs or pillars a considerable height above the ground. The rubbish hopper had been built into this framework under the water tank. After due consideration a simple rectangular form, such as is shown in Figs. 1 to 3, was decided on.

This gave a useful loading capacity of 20 ft. by 10 ft. and average depth of 7 ft. The clearance under the hopper was about 8 ft. This was estimated to hold at most 80 tons, *i.e.*, well-filled and tightly packed. The site selected was under the span of a 7-ton jib crane having a lift height of nearly 40 ft., and the hopper stood astride a small gauge railway without materially altering the storage space of the yard.

The idea was to fill a box or bucket and lift this several times per day and dump the contents into the hopper. The main preoccupation at the start of the job was to make sure that the structure was reliable, to the extent of withstanding a possible bump with the box loaded with three tons of material.

An all-metal design of hopper was considered and turned down because of the lack of rigidity, possibility of rapid weakening by corrosion, and the difficulty of getting steel and an all-concrete design decided on. The walls were made 15 in. at the bottom and 12 in. at the top, set on good foundations and well-reinforced with expanded metal. The bottom consisted of scrap 90-lb. rails, set 2 ft. apart, covered with expanded metal and enclosed in 7 in. of concrete. The main girder was enclosed in concrete, and the finished hopper has no structural steel exposed. A self-emptying hopper for this mixed material would require a slope in the bottom of about 68 degrees, which would reduce the capacity to negligible proportions.

As a compromise between ease of emptying and maximum capacity an angle of about 31 degrees was adopted. With this angle a considerable quantity runs freely at first, and then the remainder must be eased down by one method or another.

Various types of shovel, rake and bar were tried with moderate success and a certain amount of physical effort, and by these makeshift means a rate of loading varying from, say, 10 tons per hr. to 3 tons per hr. per man, were obtained. After considering all the variations of the common shovel and rake so as to draw downwards from a low position outside, or from a higher position in the hopper itself and pushing downwards from various positions, it was thought that this might be improved by eliminating the physical effort further.

A rubber travelling belt in the bottom would, of course, supply a steady feed, but this is out of the question, and the simplest method seems to be an adaptation of the rig usually used in the cupola for dragging out the incandescent bed after dropping the bottom. All that is required is a wire rope or chain laid along the bottom of the hopper with a suitable cross bar attached to the end furthest from the discharging opening, and a well-anchored guide pulley placed just outside the opening round which the rope runs to the crane hook.

This method of hopper loading is now working very satisfactorily. A fortnight's accumulation of refuse material can be loaded and dumped in several hours. The material is out of the way, and the manual handling problem has disappeared. A radical reduction in the cost of removal per ton has resulted, and the material is available at any time which may suit the contractor.

If a larger output of material be available, the capacity of the hopper can be increased (provision has been made in this case to increase the height), or the removal contractor would have to come to the foundry oftener than, say, once per fortnight. If a truck be available inside the works, the hopper might even be dispensed with altogether. It is assumed that one would make the best of the circumstances of his own particular case in dealing with a similar problem elsewhere.

Slag from Cupola

There is usually insufficient slag produced in the cupola to warrant the installation of special plant to deal with it. Low slag volume used to be the rule rather than the exception, and no doubt this largely accounted for the universally rapid wear on cupola linings, and probably had a bad effect on the metal produced. Assuming a normal slag volume as required by good melting conditions, the question of disposal again enters.

The usual type of cupola, with the slag hole to the rear, *i.e.*, opposite the tap hole, and the slag and air blowing out alternately, gives at least one man a considerable amount of heavy work, as hot slag on the ground can only be handled with a hook and then laboriously removed in lumps to the dumping point, most of the work being carried out under a shower of sparks. The use of the slag-skimmer continuous tapping spout delivers the slag in a thin fluid stream free from sluttering, and this can readily be collected in a ladle or, in the case of small furnaces, in a barrow lined with moulding sand.

If a ladle of the type shown earlier is used, the slag can be poured out on the ground. The labourer is subjected to excessive heat, and may on occasion find it necessary to abandon the slag bogie, leaving it to its own devices in the middle of the operation.

The author once saw a lead-melting furnace which delivered slag either intermittently or continuously. The slag ran down a launder or runner, where it was suddenly picked up by a strong jet of water and shot into a sump. A small chain bucket elevator worked continuously from this sump, delivering to an overhead hopper the cold slag. What appealed to the author most was the fact that the slag was instantly converted from an unmanageable material at high temperature to a uniformly granulated condition ideal for handling.

Although this is the most efficient and strikingly successful method, as already stated, its application to a cupola running only a few hours per day and not even slagging all the time, is out of the question.

For several years it has been personal practice to pour this slag into a shallow depression in the foundry yard, using water sprays for cooling the slag and prevent glare in the black-out, and this place had to be cleaned out by shovelling before each cast. Another method tried was to dig a hole about 6 ft. long, 2 ft. deep and 3 ft. wide, with sloping sides. A drawback frame with two heavy lifters was placed in the hole and the slag cast into this until full.

Several holes of this type could be used as convenient, and, using a 7-ton crane, the heavy block was hoisted above the motor lorry and broken with heavy hammers. The method got rid of the slag satisfactorily, but it was apt to fall in very large pieces into the lorry, and after several days these were often hot enough to burn the woodwork. The lorry drivers were inclined to avoid this job, and the scheme was abandoned.

This scheme does work, however, in steelworks, for example, where slag of the tap cinder is loaded in trucks for sale to blast furnaces. Then the present disposal scheme was considered. It was decided to fill up one of the concrete sumps with water so that the slag could be poured into the steel bucket. If the depth of water is, say, 2 ft. 6 in. or more, the degree of granulation is remarkable, and the amount of heat radiated is practically nil. The water boils, of course, but this results in nothing more spectacular than a cloud of steam. A bucket of the size described will deal with over a ton of slag without emptying, but the granulation is, of course, more efficient in the early stages.

There is no need to use excessive quantities of water in this process, and after due consideration it was deemed unnecessary to put in a drain to run off the water. The water supply is actually taken from the overflow from the water-cooling system of the air compressors. Thus the water run into this cooling system regularly to bring down the temperature displaces its equivalent to the slag pit, where it performs rather useful service. The granulated slag is then hoisted above the hopper and dumped where it is found to flow readily even on the 30-deg. floor angle.

Cast Iron and Steel Borings

The author has dealt with the melting of cast iron and steel borings in the cupola at length elsewhere, and it may be unnecessary to go into great detail now. The melting of cast-iron borings in the loose form independent of their size has been carried out by the author for the past four years. The cost price of these borings is 25s. per ton for cast iron and 40s. per ton for steel. The tonnage melted, including other small iron from the dressing shop, is about 80 tons per month and often over 100 tons, and this remelted metal replaces normal material, such as pig-iron and scrap.

The method is relatively simple, and the essential points are:—(1) A low blast-pressure is used, *i.e.*, just sufficient to bring the flame through the charges freely; (2) a heavy slag volume is used, which if basic, will keep down the sulphur, and (3) a low stock line. Conditions one and three are to some extent dependent on one another, as the higher the stock line the more resistance to the blast. It is a question whether a blower or a fan would be more suitable, but if a cupola were constructed specially for melting loose borings the furnace shafts should be reduced very considerably in height, or at any rate the charging door placed lower.

The cupola used by the author is a 32-in. balanced blast furnace fitted with a self-slagging runner, and the metal is collected in 10-cwt. ladles. From this it goes to the casting point. This metal has been used for castings, and on test has given high tensile test results owing to the low carbon possible. It may also be cast in chill moulds and stacked for remelting. Many attempts to use steel turnings in the loose form were made in this cupola, but results, although metallurgically successful, were not worth the trouble.

A combined casting process was developed in which the steel turnings form the chilling medium and in the act of casting the cast iron absorbs about 33 per cent. steel cuttings. This process has been very successful during the past year. The product is a intimate mixture of cast iron and steel of high specific gravity and of uniformly low melting point. It makes an excellent base material for high-duty irons, giving a close-grained casting suitable for surfaces subject to wear.

Abrasive Wheels

In all large engineering establishments there is a considerable quantity of broken grinding wheels of various types discarded regularly. Those of the silicon carbide type can be utilised in several ways in the foundry. It has been suggested that these be used as refractory bricks in certain positions such as tap holes and similar places. It is possible that they may be used as a ladle addition if ground up. The most promising use is the addition to the charges in cupolettes of small bores.

The addition of this material broken to about 2-in. size gives an additional amount of heat, which is very useful in the first charges. There is, therefore, a small amount of refractory slag produced which need not cause any trouble. In the writer's experience an increase of about 100 deg. C. has been observed.

London Branch

Running and Risering Iron Castings

DISCUSSION INTRODUCED BY MR. E. M. CURRIE (Member)

MR. E. M. CURRIE said he did not propose to give a Paper on this subject but to start an informal talk on a matter which was often too easily briefly dismissed as gating the mould. It might be claimed that there were problems to be considered, such as labour, management, costing, or metallurgical, which might be considered more important than how the metal got into the mould. However, in his view there was not one single operation in the foundry industry which was more important than any other and to start right was to finish right; the job of the foundry was to produce a perfect casting.

A general study of the foundry industry showed that there was, on the average, some 5 to 6 per cent. of all castings made which were defective and, taking the industry as a whole, this meant there was nearly a quarter of a million tons of castings which had to be made again every year. The metal, of course, was not lost but time was irretrievably lost, as were all the materials, other than the metal, which made up castings. There was no need to stress the importance of that at the present time.

He had had the opportunity during the past 10 years to study the "defective" records of some 40 foundries in this country and on the Continent. This showed that some 40 per cent. of the total number of defectives was due to sand, slag and scum in the casting. The main point was that proper gating would definitely prevent slag getting into the mould and the sand or scum getting into the casting. That might seem a rather bold statement but the point had been so well established in the case of the foundries he had mentioned that it could be well applied to the whole industry. The scope of this subject was vast and well worthy of further practical research. He had intended in this talk to try and deal with both gating and risering, but in the time available, in order to do at least bare justice to one of these subjects, he must concentrate on gating, and deal with the basic principles in a manner which he hoped would stimulate interest.

Reducing Defective Castings

There was no magic formula for getting rid of troubles in the foundry from the causes he was going to mention, but some slight degree of imagination and commonsense applied to most jobs would easily halve the number of defective castings. Of course, in the case of the supervisory staff, their difficulty was in making sure that their instructions to the men were effective and lasting. Therefore, some method of stirring the imagination of the men and effecting a lasting memory was absolutely necessary. He had found that picturisation was ten times more effective than any number of talks, but it must be fairly novel to be remembered. Owing to conditions in the foundry there were obvious limitations in what could be done in this way in the present state of the art of photography. A method he had found effective was to make a series of instructional slides dealing with gating from the very start and carry on to the finish where the metal enters the mould, and to show afterwards one or two examples of actual pouring practice, using simple castings, which drove home the points which were being made.

Mr. Currie then showed a series of slides of the nature he had indicated, with which he took his audience from the ladle to the mould, and demonstrated the principles he had outlined in his opening remarks. Speaking of the many attempts that had been made to improve the ladle form, he said the ideal, if it could be attained, and made controllable, would be the bottom pouring ladle, but the stage of its real effective use had not yet been reached in the grey iron foundry. The next best thing was the tea-pot spout, which should extend right from the bottom of the ladle. The whole idea, of course, was to start with really clean metal. The practical man did not need telling what happened if this was not the case, but it was a point that had continuously to be emphasised.

Pouring and Basin Shape

Passing to the question of pouring, he remarked that it might be said his illustrations were obvious, but he stressed the fact that the slides were being used to stimulate imagination on the part of the moulder, who probably knew most of these things but was very apt to forget. In the same way, discussing basin shape, he admitted the points brought out by the slides were more or less obvious, but, he asked, how often were the errors shown on the slides far too often seen in the foundry. It was no use saying that the obvious improvements could not be done or that there was not time to do them. They could be done quite easily—often in shorter time than to do the job incorrectly. The majority of foundries, who took a pride in their work, would go to the extent of using runner bush machines, plate patterns, and making the runner bushes in oil sand or anything they needed in order to make the perfect casting. This made it easier for the moulder to keep his basin full, which ensured clean iron going down to the mould.

Showing slides to illustrate a few of the faults that could occur, Mr. Currie laid great stress on the necessity for having a clean basin, for a clean basin meant that half the work of getting a clean casting had already been done. There were far too many instances in which the runner basin was left in an untidy state which could be avoided with such little more trouble to make a smooth basin. It was quite a simple matter to cure that trouble, and some slides were shown to illustrate that point.

On the question of down-gates, slides were shown of the faults which Mr. Currie said he had seen hundreds of times within the past 10 years, and he followed up with slides showing how these faults can be remedied in a simple manner. He suggested it would pay the members of supervisory staffs to produce a little booklet setting out the methods which would suit their own particular foundries, giving the types of runner and the sizes of runner most suitable, and also methods of trapping the dirt. This would be a permanent reminder to the men of the methods which had been proved to be very effective. In one example, if the runner bar was larger than the down-gate, the runner bar would never be kept full of metal and dirt could easily reach the in-gate, and it was pointed out that in order to apply the fundamental principles of gating, it was necessary to consider very many points of detail of this nature exhaustively and fully. Special attention was paid to the question of dirt traps, and it was pointed out that although this could be gone into in great detail in each foundry, care had to be exercised in what was taught in that respect. For instance, Mr. Currie said he had taught a certain foundry at least 10 different ways of trapping dirt, and about a month later he found that one moulder had incorporated several of these different methods in the one single runner system. As to how the metal ever reached the mould from the basin he had never ceased to marvel at!

Slag Formation

Methods were illustrated of how the moulder could be instructed to prevent slag formation, and it was emphasised that it would pay to take three or four average examples of castings made in a particular foundry and study them closely and determine how the gating could be carried out. There would be one best method, although there might be half a dozen just as good. The moulder should be taught exactly how the metal entered the mould, and why metal did not cool down uniformly. In this connection crayon drawings in colours showing the operations and temperature differentials were of great use, and Mr. Currie again showed slides illustrating what he meant. Instruction of this sort in connection with sizes of runner bars, gates and basins might seem to be somewhat troublesome, but it had been proved well worth while no matter what the type of foundry. Proper methods could be instilled into the moulders without any real trouble at all when the men had had explained to them what was being done and what was the ultimate aim. The men should be shown the full results of following these best methods. The ciné film was extremely useful in this connection as compared with the still slide, for it was then possible to demonstrate the exact process from start to finish in motion. The possibility of instructing the moulders in the production of the perfect casting in this way was strongly emphasised, and in order to drive home these points Mr. Currie then showed some colour films of the running of castings and the flow of metal, which he claimed were unique.

The first film, he said, wsa produced by the Greenlee Foundry Company, a Meehanite licensee in the United States, as the result of their experiencing a considerable amount of trouble from defective castings, and Mr. Currie said he had been assured that the interest taken by the moulders in this particular film had been remarkably effective in reducing the number of defectives produced.

Parts of the films were run through at slow speed to enable the action more clearly to be seen, and the second film showed further pouring and casting of several different moulds and gating systems.

In conclusion, Mr. Currie expressed his thanks to the Meehanite Research Institute for allowing him to show these films and slides to the Institute.

DISCUSSION

MR. J. F. KAYSER, Assoc. Met., said that this was one of the most remarkable Papers he had ever heard presented to the Institute. He thought that it was the sort of Paper which it would be well worth while bringing to the notice of every foundry in the country, for he was certain it would do a very great deal to relieve the pressure on foundries at the present time. He had been rather surprised to hear the author indicate that some people did not appreciate the importance of running and risering. There might be problems which were equally pressing, but the author would agree that there was nothing in the industry which was more important. It might be true that, as far as the general foundryman was concerned, there was 5 to 6 per cent. of defective castings, but, as far as the general user was concerned, the castings delivered were usually so bad that certainly over 20 per cent. of them ought never to have been sent out!

Runner Basins

Commenting on runner basins, he pointed out that the slides showed them to be quite full of metal. Personally, he had never handled cast iron at all, but had dealt mostly with high-duty alloys varying in weight from a few lbs. up to half a ton, and he did not always find it was the best practice to have the basin full, because the runner basin was used in many cases to get the metal into the mould, and it was also used to some extent as a vent to allow the escape of, he would not say gas from the mould, but the air. It seemed to him to be rather a question of size. In the case of very small castings, it seemed to him it would be rather difficult always to keep the runner basin full, as it was necessary to stop, and, when dealing with the more expensive metals, how did one know when to stop, because, with small castings, it was better not to have a riser, but just a runner?

At the present moment he was not engaged in making castings, but in using them, and had, fortunately, got into touch with a number of sources of supply of Meehanite castings. It was only recently he had seen a foundry where these castings were produced, and the thing which appealed to him was the neatness of the mould. There was no loose sand in evidence. The moulds looked real masterpieces, which was what they always should be. It had been said that horn gates were not so popular. Was that anything to do with the fact that it was almost impossible to get a horn gate that was really clean? In general, it had to be pulled out of the sand and, personally, he could never see how they could be obtained clean.

Finally, he asked whether the British Cast Iron Research Association could carry out a complete research on the lines indicated by Mr. Currie's films. The expense would not be colossal, and the use of colour actually facilitated matters. In another branch of industry he had used motion pictures quite extensively, and much better results were obtained with coloured films than with black and white.

A Film and Slide Library

Mr. E. H. Brown, speaking on the question of wasters, said his experience was that some 60 or 70 per cent. of wasters were due to gating troubles. It was quite true, as Mr. Currie had said, that there was no magic formula in the foundry, but everybody wished sincerely there was, so that everything could be laid down on hard-and-fast lines. Mr. Currie had shown something which he himself had never seen before. These instructional slides were of the greatest possible interest, and, in view of what Mr. Currie had shown, he again stressed a point he had mentioned on other occasions. Mr. Faulkner and the late Mr. Oliver Stubbs were very much interested in it, which was the establishment of some film and slide library through the organisation of the Institute, which would be available to any of the members for instructional work. He raised this question again because he believed that all those present appreciated how much benefit they could obtain from a series of films such they had just seen. He had put into one of the foundry technical courses some 200 slides which he had at the time, and he believed they were still available throughout the country somewhere and could be organised. He was quite willing now to provide some 50 or 60 slides which he had, but he did not know what other people would be willing to do. Personally, he felt the time was ripe—and this meeting emphasised the point—for some form of organised instructional work along the lines he had indicated which would not incur any great expense compared with the results to be obtained.

Mr. L. E. Slater said he noticed in the illustrations there was no stopper in any of the basins. With regard to slag or scum, might not this be due more to turbulent flow in the mould? That, of course, was due to incorrect design of the in-gate, and he was pleased to see one illustration in which the entry end of the in-gate was larger than the one that joined under the channel. That was a point to be stressed. Could Mr. Currie give any information as to preventing turbulent flow, because more often than not, to check the metal it was necessary to have the entry into the riser larger than the entry into the mould, because the spinner gate or riser was often used as a feeder as well. Referring to the whirl gate, he asked whether Mr. Currie could give any information as to whether the metal should go clockwise or anti-clockwise.

Mr. C. H. Kain remarked that, having regard to what had been said for many years about the difficulties of founding, and of founding being an art and not a science, and the like, he felt it was a very bold and constructive step on the part of Mr. Currie's oganisation to isolate one factor in the production of castings and to study it just as the more highly technical metallurgical aspects were normally studied. At the present time he was very interested in two aspects of the Paper. One was the diagnosis of wasters and the other was education. Could Mr. Currie give further details of the analysis of wasters which led him to the statement that 40 per cent. of wasters were due to gating troubles? Also, he was very much involved in various educational schemes both for foundry apprentices and, in some cases, for foundry managements, and he wished to ask if Mr. Currie could give some idea as to how the information he had given during his talk was put across in the foundry; how did he tackle the broadcasting of this information in the 40 foundries to which he had referred?

Author's Interim Reply

Mr. Currie, replying to the discussion as far as it had gone, said it had been his experience that it was not so much a question of getting this information over to the men as to the foremen and the supervisory staff first and foremost, because, to a certain extent, unless the foreman himself really understood and laid out his programme to fit his own particular types of casting, it was useless for anyone to go to any particular foundry and deal with such a big subject in a very broad manner. Such a method did not achieve results. It was necessary to take a particular foundry and its particular castings in detail, and the best way of doing that was to convince the supervisory staff first of all.

Replying to Mr. Kayser on the question of keeping runner basins full, he agreed that a great deal depended on the type of metal being dealt with. He had realised that from the start, and had confined himself to the gating of grey cast iron and high duty irons. Obviously, as he had shown in his early slides, a good casting depended on making sure of getting good clean metal, by thorough skimming or by means of teapot spout ladles. He agreed with what Mr. Kayser had said with regard to the horn gate. In these days there was not time available to make a horn gate properly. It took a good deal of fixing, and to be used properly it must be fitted and packed properly with sand and withdrawn cleanly, and even after all that it was difficult to be sure it was absolutely clean. Furthermore, where there was an ordinary runner bar at the joint of the mould, it was always possible to see whether the mould was clean, but that was certainly not the case with horn gates.

As regards what Mr. Brown had said concerning his statement of the percentage of wasters due to the gating problems, Mr. Currie said he had obviously had to take a relatively broad view in arriving at such a definite figure as he had given previously. It could be said, as the result of the analysis of the 40 foundries already mentioned, that between 60 and 65 per cent. of all wasters was due to what might be classed broadly as moulding problems, and when these moulding faults were split up it was surprising how much could be put down to bad gate or bad basin practice. That, of course, might be further detailed to such things as making the runner bar or in-gates in black sand instead of facing sand or some similar fault, but that was merely one of the points which linked it to the gating system classification. He certainly agreed with Mr. Brown that it would be an excellent idea to have a library of instructional slides, and he believed he was correct in saying that the Institute, as a whole, was already doing that. At the same time there was no reason why the London Branch should not carry out the same idea as well. Everybody had the good of the industry at heart, and would be willing to help in that direction. The Meehanite organisation would, he was sure, be willing to co-operate.

Stoppers and Whirl Gate

It had been mentioned by Mr. Slater that the illustrations did not show the use of stoppers. That was true, and the reason was that the majority of to-day's illustrations dealt with small castings. Where it was a case of a casting weighing a ton or more it probably paid to put a stopper over the down-gate, but frankly he did not like an iron stopper for the down-gate for several reasons. Too often did the moulder continue to use it when the bottom was burned away, and the first iron flowing into the basin was certain to wash dirt straight down the down-gate. Therefore, wherever possible, everything should be done to make things foolproof. He did not agree with Mr. Slater that scum was caused by turbulent flow if the runner system was made clean. Wherever possible patterns should be used. If necessary, facing sand should be used around these patterns to obtain a good clean finish.

With regard to the whirl gate, it did not matter whether the metal went clockwise or anti-clockwise. The important thing was that the inlet from the down-gate should be large enough to keep the whirl gate full so that the outlet did not take away slag and dirt, and secondly, the inlet to the whirl bob should be in the proper positional relationship to the outlet and not, as had been seen from some of the illustrations, directly opposite.

Replying to Mr. Kain on the question of the analysis of wasters, he said he used a standard detailed daily record sheet. Someone once said there were some 57 different ways of making a defective casting, but he did not know the exact number after years of study. He had tried hard to list them all at various times and had a feeling that there might be hundreds, but, of course, in daily foundry practice it was impossible to get down to such detail as that. Therefore a reasonable limit must be placed when making out a weekly or daily sheet for the analysis of defectives and he would be pleased to show anyone interested a sheet which he used for that purpose. As to how this information could be inculcated into foundry practice, all he could answer was that it could be best done in the manner he had done it that afternoon. He had found that in nine cases out of ten the moulder was keenly interested in his job and he would always go and see something that he could argue about, even if it were outside working hours. He had seen some very large audiences at such times and even bigger ones if it were in working hours.

Whirl-Gate Design

MR. H. G. SUMMERS expressed the view that the average practical foreman had tried all the methods that had been illustrated by Mr. Currie but did not then get 100 per cent. It would be interesting to have the author's view with regard to temperature as well as design of whirl gates. Something had been said about the risers letting the dirt out of the mould but it should be stressed that risers did not take the dirt out of the metal or clean the slag out of the mould. Horn runners were not in use as much as they used to be but he saw no reason why they should not be. Speaking of turbulence, he said it was well known that in the case of high-duty metal, turbulence would bring out the scum.

MR. G. C. PIERCE remarked that, unless he had been missing something during Mr. Currie's talk, no mention had been made of the most efficient runner, viz., the spinning runner. He also had tried to analyse at different times what was the percentage of wasters due to runners and runner basins, and joined issue with Mr. Currie's figure of 20 to 30 per cent. It might be that Mr. Currie had been particularly unfortunate in his foundries, because he felt that this percentage was very high. He would rather say that sand condition and sand running were responsible for a greater percentage than either gating or running. He agreed that the runner must be kept full, and that applied to most metals. Again, he felt he must join issue with those who suggested that the runners could be allowed to empty themselves, or nearly so, and allow the air to come down to create a vent. Most emphatically, if he wanted a vent to be created in a mould, he would take care it went through another place and not up the runner stick.

Mr. McRae Smith pointed out that nearly all the illustrations that had been shown were of side running, and asked if similar demonstrations had been given by cinema to show the advantages of top and other forms of running. In the case of the very small pulley which was shown, perhaps side running would be beneficial, but had the author had experience of picturing the flow of metal in a spoked pulley run by two small jet runners on the central boss or from a ring runner from the outside? With regard to the flat castings illustrated, he realised the illustrations were used for the purpose of showing good examples of getting metal into the mould without scum or slag, but to run the flat castings in the manner shown it seemed to him would result in cold metal getting to the side of the casting remote from the runner, and there would be a great tendency to create hot spots. Finally, he asked if Mr. Currie thought it would really be a practical proposition to run flat plate castings of the type shown from two sides if there was to be uniformity of structure in every part of the plate.

Temperature of Pouring

Mr. Currie, replying to Mr. Summers' question on the temperature of pouring, said that, as a general rule, he poured as hot as possible. In recent years he had taken great interest in high-duty irons, and with their short freezing range it was necessary to melt and pour as hot as they could be got out of the cupola. As to Mr. Summers' disagreement with the view that risers would bring dirt out of the mould, it was perfectly true that the main function of the riser was to feed a section of the mould and to make up for any loss due to shrinkage of the metal in that particular quarter. At the same time, he felt sure htat Mr. Summers' experience would agree with his own that in the case of certain castings, such as cylinder liners, where it might not always be possible to get a good ring of pop gates all round the top, it might be necessary to use runners on the one side. There was thus a tendency to scum formation, which was swirled round to come up again on the opposite side to the runners, and it would be found that a riser here would take out that scum and slag. It was purely a question of the type of casting being dealt with. As to turbulence, it was well known, of course, that this, in a ladle, would bring the scum to the top, but there was no necessity to apply turbulences or shaking up in a runner system in order to obtain the desired results.

In reply to Mr. Pierce, he said he had shown one or two designs of the spinning runner, but, personally, he would not use the type illustrated at all times, because he felt considerable improvements could be made in it. Perhaps he had rather emphasised side-running, as mentioned by Mr. McRae Smith, and he had to admit that, to a certain extent, it might be difficult to produce a film such as that suggested. Of course, he was well aware that very many castings were top poured. The question of whether it was better in the case of a gear to put the runner on the centre boss and let the metal flow outwards instead of the reverse was one which foundrymen could dispute and argue about for hours. In cases where the outside rim was exceptionally heavy or where teeth were to be cut, the side runner might create dangerous hot spots, and there may be porous spots in the bottom of the teeth. In such a case, he would agree that running from the centre boss was the best. If, however, they were dealing with a metal which had high shrinkage, centre runners directly on the boss could be dangerous. He had found it an improvement in such cases to put a riser on the centre boss and to gate directly into the riser.

Mr. McRae Smith: That is what I meant.

Mr. Currie, continuing, said it was possible to go on for hours on a subject like this. All he was trying to do was to stimulate imagination on a broad chosen series. It was possible to get down to exact details of many similar cases, but there was a time and place for all of them. In the case of the flat casting mentioned by Mr. McRae Smith, admittedly the way of casting that which was shown may not be the best, but probably it suited the particular foundry and the method adopted could be adapted to the conditions. It was necessary to consider the type of casting first. A floor plate could be flushed from one end. A surface or jig plate, which must not warp or distort, may even have to have to runners all round it. The example shown was a type rather than a recommended method of gating.

Rod Feeding with Small Riser

Mr. V. Warren, speaking with regard to high-duty irons, said he had not been associated with them for very long, but he realised they must have a feeder head where there was a thick and a thin section. Generally, there would have to be a big riser and, unless there were no facilities to take these risers off with a flame cutter of some sort, it would be a big job to saw them off by hand. Therefore, such castings must be rod fed if a smaller riser were used. When doing that, however, he realised the work needed to be in the hands of an efficient moulder who knew what he was doing.

Mr. Currie said he was sorry to tell Mr. Warren that he himself was antagonistic to rod feeding at all times, because there were so few skilled moulders who knew how to use the feeding rod properly, especially with high-duty irons in the low-carbon/low-phosphorus series with accelerated cooling rates. In such a case one was running into great danger in trying to use the rod, and he preferred to have a riser of a proper size in relation to the section to be fed.

MR. CURRIE, continuing, said there was really no difficulty in knocking off risers up to as much as 6 in. square, where the pad at the bottom of the riser had been shaped properly on to the particular job. After a start with the chisel the riser would break off cleanly.

MR. WARREN said he did not like rod feeling, but there was always the great difficulty of getting large risers off.

MR. CURRIE said Mr. Warren was very fortunate if he had a moulder who knew how to use the feeding rod, because the majority did not.

MR. J. H. KING, commenting on the stress laid by Mr. Currie on the proper skimming of the ladle before pouring, said he noticed that in some of the pictures there was an accumulation of slag. Was that intentional?

MR. CURRIE said it was necessary to make a good demonstration. If the ladle had been thoroughly skimmed, it would not have been possible to see the slag effects clearly, so that, to some extent, the presence of the slag was intentional.

Vote of Thanks

DR. A. B. EVEREST, proposing a vote of thanks to Mr. Currie, said they had listened to a unique talk in which one detail of the whole foundry problem had been isolated and studied in a very thorough and quite unusual manner. The talk had been excellent, but it had left him feeling very much like Oliver Twist—he wanted to ask for more. On the question of the percentage of wasters, he said, this raised many points, and everyone would have liked to have heard more about the influence of other factors, such as speed of running, dimensions of in-gates, risering, etc., in relation to getting sound castings. Obviously, the author could not deal with risering in the time available, but the pictures were remarkable in that they gave quite a new insight into the behaviour of the molten metal entering the mould. The Paper suggested all sorts of further lines of attack, which he hoped Mr. Currie might consider at some future date.

MR. P. A. RUSSELL, B.Sc., who seconded the vote of thanks, said he had come specially from Leicester to hear this talk, and felt that his time had been very well spent. Although he had some reputation of being a metallurgist, he was far more interested in making a good casting. Everybody could copy Mr. Currie's methods. On occasion, when there had been some difficult running problem, he had actually made an open sand mould and studied the manner in which the metal entered the mould. One point was made clear, however, and that was that, whenever liquid iron was in contact with air, slag was formed on the surface. Clean metal might be going into the mould, but in the open air slag was formed. If a closed mould were used and a comparatively reducing atmosphere, that did not happen. That was a point he had noticed in running open sand experiments, and the cinema views that had been seen that afternoon rather confirmed this.

He always tried to impress the people in his foundry that the runner was the most important part of casting. A casting might weigh 10 cwts., and every ounce of the metal had to pass through a comparatively small space and was therefore subject to the most severe conditions. He was glad Mr. Currie had recommended the use of facing sand for runners as well as the mould. As chairman of the Cast Iron Sub-Committee of the Technical Committee he could inform Mr. Brown that the Technical Committee had formed a slide library and if anybody had any slides which they were willing to lend, Mr. Bolton, the assistant secretary of the Institute, would be more than delighted to hear about them. There were, of course, a great many difficulties particularly in regard to indexing. He himself had 200 slides, many of which were copies of textbook things and were probably identical with those which Mr. Brown had. However, he was sure Mr. Bolton would be pleased to help in any way possible.

The BRANCH-PRESIDENT (Mr. R. B. Templeton), before putting the vote of thanks to the meeting, expressed his own appreciation of the talk by Mr Currie.

The vote of thanks was then put to the meeting and was accorded with hearty acclamation.

MR. CURRIE acknowledged the vote of thanks.

West Riding of Yorkshire Branch

The Production of a Diesel Engine Valve Bonnet

A REPORT OF A SERIES OF DISCUSSIONS

[During the 1941-42 session of the West Riding of Yorkshire Branch a number of meetings were devoted to the discussion of the foundry technique to be adopted for the production of a specimen casting, the description and specification for which were as follow: Cast-iron diesel engine valve bonnet suitable for either inlet or outlet valve. To be true to shape, free from scabs, sand holes and draws. To withstand high temperature and pressure without distortion and growth and to meet B.S.S. 786, grade 2. The valve spindle guide to be bored and ground to fine limits. The pattern and core box to allow for $\frac{1}{8}$ in. machining. The casting is shown in Fig. 1.

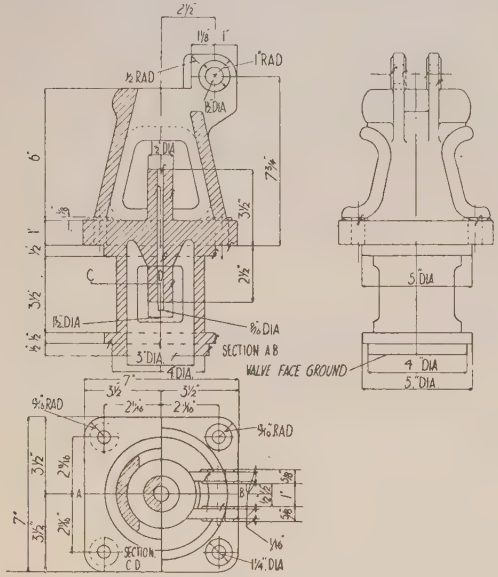


FIG. 1.

It was proposed that the production of the casting should be considered from the repetition viewpoint, where batches would be required of one-off, 25-off and 200 or more off. The discussions were divided into the following sections: (1) Moulding practice; (2) core-making and core-drying; (3) metal; and (4) potential defects. Each section was introduced by a member of the Branch whose remarks, together with the discussions are published below.]

I—MOULDING PRACTICE

MR. J. TIMBRELL, JUNR., who introduced this section, said the job was broadly a single-handed one, equally suited for bench, floor, hand plate, or moulding machine production in, say, 14-in. by 12-in. boxes, approximately. Comparison of the pattern with the coreboxes and drawing would give some indication of the section, core-making and the methods to adopt. The question of running, where to place the runner, what type to use, what style of feeder, if any, etc., had to be considered. The section varied. The casting shown in Fig. 1 contained a rather heavy section which would show a tendency to some porosity with certain irons. It was expected to be quite sound after machining on account of the valve stem working in the hole. To make this part solid, some form of feeding would appear to be necessary. In ordinary loose pattern production, rod-feeding might suffice, but where pattern plate production is used, self-feeding was preferable, if the self-feeder could be so designed as to give solidity to the casting.

Gating

On the question of runner or "gate," as it is more commonly termed in Yorkshire, a fairly safe rule was to put it in the least important part to help toward uniform cooling as far as the job would permit. This feature is shown in Fig. 2. This rule would apply in either loose pattern or plate. When worked loose, the moulder was usually left to please himself where to run it, so trial and error may decide it, based, of course, on the experience gained in similar work. Under these conditions, the style of runner consisted of a down peg and straight in-gate. This was not always suitable, and some form of bypass or dirt trap may be required to take the first rush of iron. This may often be desirable, but, of course, much depended on the cleanliness in bushing up and the style of the straight down- and in-gates. Runner skimmer tins or a ball-stopper is often advantageous for ensuring clean pouring.

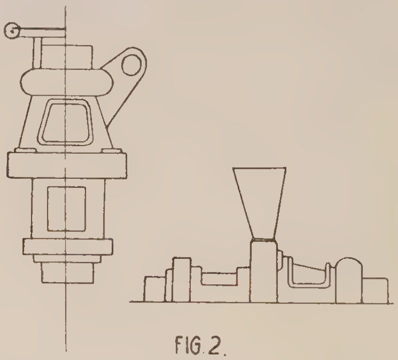


FIG. 2.

Potential Moulding Methods

The running and feeding methods having been established, the question of production must be considered. The pattern as supplied by the customer would most likely be split, so for one-off this would be made in the usual way, in the best available moulding box, that is, it would be first half-rammed up off a board or plate and so on. For pattern-plate moulding, there were several courses open. These were controlled to some extent by the tackle available. Obviously there must be no twist or cross joint.

Fig. 3 shows the simplest way of mounting patterns, but not necessarily a good one for this class of work unless the plate was fairly thick and the box pins and pinholes were a good fit. The top was usually rammed up over the bottom half before the plate was drawn—this sometimes involved mending the mould. If the top was rammed up separately, a box part was still necessary underneath, and then, after rolling over, removed. This method would possibly give cross joint, even with a dozen-off, if the pattern were so mounted. There was only the saving in the mounting time (if any), by putting a half each side of a single plate, as is shown in Fig. 3.

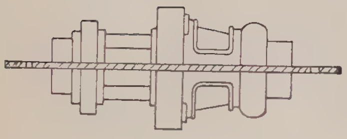


FIG 3

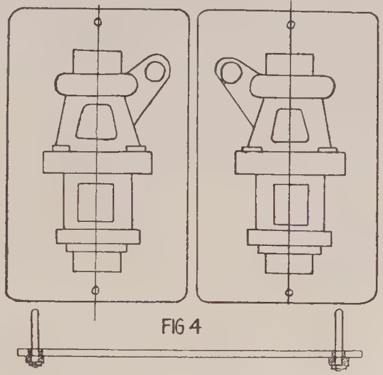


FIG 4

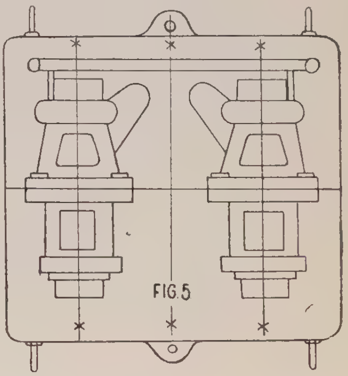


FIG.5

Fig. 4 shows a good way for double-hand plate production. In this method, each half of the pattern is mounted on a plate; the tops and bottoms are rammed up separately and the plate drawn off. Cast iron could be fastened to the thin plates and drilled template holes provided. Fixed pins give rigidity and eliminate the amount of cross joint which loose pins would communicate.

Fig. 5 shows the two halves rigged up according to the usual setting out method as a reversible job, involving the making of tops and bottoms alternately. The runners would be, of course, dowelled in place and taken off for tops or bottoms. Two in a box would make this a double-handed job. Really good tackle to almost tool-room standard would be essential for accurate work from reversible pattern plates.

Sand Control

Recapitulating the points of the moulding aspect, it should be pointed out that sand may be considered as part of the subject. This, admittedly, was controlled to some extent by the shop routine. For machine moulding, facing and backing sand were usually prepared in bulk for the operatives. Quality and bond were important, but one of the main items in any sand preparation was the moisture content and one could say in all green sand moulding, be it hand or machine production, the moisture content was one of the main factors in the production of sound castings. Too wet a sand, as was generally recognised, would set up agitation and form scum. On heavy section work the agitation would probably come to a stop and the pressure applied by runners and feeders would compress this scum into the shape, but machining would most likely show it up in the form of "honeycomb" or blowholes. Coarse or fine milled coal dust came into the sand question, and one must consider the amount, etc. A good-looking skin was not always a sure indication of soundness. In certain classes of work where the ramming or squeezing was not too severe, coal dust was an addition which allowed latitude in both directions. Too much coal dust with light work would involve much waste and in some cases create so much gas that castings would not run sharply or cleanly.

Bosses on the Flange

MR. W. G. THORNTON said one or two snags had been left in the drawings to raise difficulties and create discussion. He would like to ask the opener how he would deal with the bosses on the flange, from a repetition production point of view.

MR. TIMBRELL said these could be carried through to allow "strip" or cored out underneath if the drawing office insisted on these being left on the job. Often the authorities over design would allow milling the washer faces from a level flange.

MR. F. K. NEATH asked whether that was a point that should be left to the patternshop to deal with rather than the moulding shop.

MR. BLAKISTON said that was a matter for the drawing office, and described an ingenious method of drawing these spot flanges in before stripping by the use of electric solenoids set in operation by the controls before the "strip."

A MEMBER, agreeing with Mr. Blakiston's views, said that from a production point of view probably a spot face was preferable instead of machining the flange.

The BRANCH-PRESIDENT (Mr. W. Fearnside) pointed out that returning to the drawing office was inadmissible, as this was supposed to be a job that had been brought in from the patternshop, and it had to be made irrespective of the defects or difficulties.

MR. H. FORREST said they had to consider a casting which may come along for one off and then later develop into an order for 25, 50, or several hundred. Whilst they may "get away with it" for one off, new problems arose if they had to make more, and the firm giving the larger order probably required a reduction in price for quantity. They had to consider first the matter of a job that was insufficient to warrant plate moulding, but which may have more implications when it came to attaining 200 off. The moulder would possibly have to make some provision to assist in getting the centre absolutely solid.

MR. NEATH said he would like the lecturer to explain in more detail how he would set about the production of 25 or more off, assuming the patternmaker had put on the bosses. It was a fundamental factor of moulding that they had to deal with the bosses. Was he going to make up 25 with the two-pattern moulder or would he go to the expense of a plaster block?

MR. TIMBRELL said shop routine would more or less control the mounting. A plaster block for small orders did provide a way out. It would carry metal "tippings" on the high spots where expense warranted it. The hard setting materials, however, whilst taking longer to set, gave a much more satisfactory result. Dovetailing the bosses and drawing them in could also be used.

In a reply to a young member who suggested casting vertically, MR. TIMBRELL felt, if it were run on the bottom, there would probably be porosity on the valve seat.

MR. F. OLDERSHAW said the job was only about 12 in. long, and it occurred to him that the whole thing might be blocked out and made entirely in the coreshop.

MR. BLAKISTON pointed out that the members were also concerned with the speed of running. This was a very high duty casting, subject to great heat.

Chilling Problems

A MEMBER suggested a metal chill should be inserted down the centre.

MR. TIMBRELL felt under these circumstances the drill would tend to wander.

A MEMBER suggested that in these strenuous days, when it was difficult to maintain the correct analysis for non-drawing types of irons, a cast-iron chill pin was almost essential for sound results; a steel pin for some reason gave trouble in certain ways in the machine shop.

MR. S. W. WISE (Hon. Secretary) said as the question of chilling had been raised, personally he would not think of putting a steel chill in a cast-iron product, and he gave an experience of his own some years ago which had satisfied him that it was not desirable.

ANOTHER MEMBER said he would not be inclined to drill the hole, but would core it out.

MR. L. TURNER said prospective makers would be exceptionally lucky if there was not a cavity or two in this job. His personal idea would be to rod feed to keep the middle working.

MR. NEATH pointed out that if it were a one-off job the foundry would have to make it in the best method and material available. This might apply even up to 25 off. The question of metallurgical control for quantity production was a subject to be dealt with in a later discussion.

The BRANCH-PRESIDENT said that, personally, he believed that any ordinary foundry would have to regard it as a special job or else simply refuse it.

MR. BLAKISTON said certain fundamental factors still had to be considered, such as, for instance, was green or dry sand to be used? It was necessary to make it feed itself if possible, and moreover it should be made as low in cost as possible, yet it had to be made foolproof.

Sand Control

A MEMBER remarked that the question of sand was an important one, and he felt it was desirable to have a fairly free venting sand in order to get solidity.

MR. TIMBRELL said if existing sand supplies were to be used he would pay special attention to the moisture content.

A MEMBER said he would use dry sand for a one-off job and so eliminate this aspect of sand control.

MR. THORNTON, speaking from the repetition point of view, said he worked with a very dry sand. He would tackle the job on a power press. He would run it with a very small runner and would eliminate risers. He would put a chill round the inside of the boss, and initially he would make an experimental casting. With regard to the bosses, he would see whether they could be eliminated, but, if not, he would draw them out mechanically.

II—CORE-MAKING AND CORE-DRYING

MR. J. TIMBRELL, SENR., opening the discussion, referred to some sand models which had been prepared to help cover many of the points mentioned and are common to this style of core-making. There are two cores, and in each case the spigot boss has to be formed on the inside of the cores, either by bedding in split half-boxes or ramming up from the open end of a full box, with the whole spigot in place on the bottom, as is shown in Fig. 3 (page 235).

Bedding-in has disadvantages; usually the half-spigot is fastened to a cross-member with dowels, but this has to be rapped down into place, and unless large dowels are used or substantial side pieces, after repeated use the tendency is to get the spigot out of line, when the two halves of the core are put together the spigot is cross jointed. Moreover, with bedding-in, unless the core sand has a good green bond and air-drying qualities, packing sand has to be rammed in to maintain a true shape after turning the core out on to a coreplate (Fig. 4).

For quantity production cast-iron packers, put in, and left in during the drying, will preserve a true shape and is indicated in Fig. 6. Another way is to dry one half-core and turn the other half on to it, a method which saves jointing.

The other method for making a full core is to form a full spigot on the bottom "lid" and ram up in one piece from the open end. No spigot packer or packing sand is necessary with this way, but a well-bonded sand, capable of maintaining its shape in the green condition, is required. One or two points in favour of this method are:—(1) It eliminates jointing, and (2) generally gives a better-shaped core.

Level core plates are indispensable for true half-cores, for any cores not dead flat when assembled will cause flash at places where it is not easy to clean out. Rubbing two uneven cores together to make a joint will aggravate the error by reducing the diameter of the spigot and the core body itself will be out of round, and thereby cause flash in the bottom opening when the core floats under pressure during the pouring of the mould. This is shown in Fig. 5.

For intensive production of large orders, dummy half C.I. boxes are the best; these are easily formed from a sand block made from a half core and filed away to even section all over.

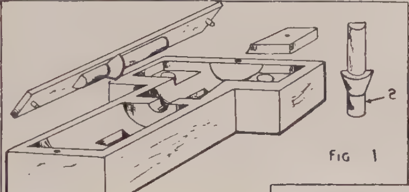


FIG 1

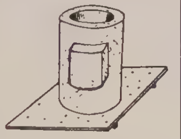


FIG 4

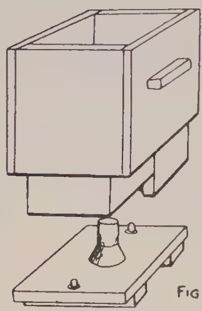


FIG 5

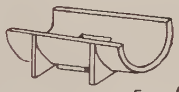


FIG 6

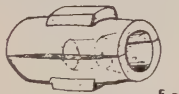


FIG 5

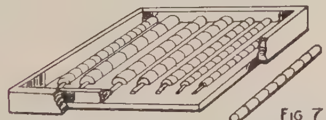


FIG 7

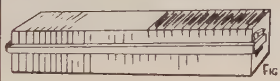


FIG 8

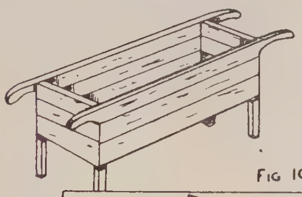


FIG 10

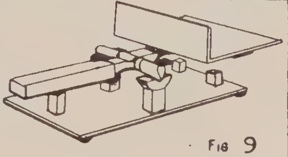


FIG 9

Chill Pins

Digressing for a moment, chill pins were mentioned in the last discussion. Prints for these should, of course, be added on to the spigot pattern, and where the cores are assembled in the mould in halves, a check for alignment ensures accuracy. If the cores are in one piece, the chill pin can be pushed back into one core and brought forward into the other, when the two cores are in place in the mould.

It may be of interest to describe a method of making these C.I. chill pins in quantity from a reversible half corebox. Several different sizes of half patterns are set out equidistantly on the bottom of the corebox. The two halves are put together and several of these moulds are assembled in a row, a long clamp being used to hold them. If the pins are V-notched every half inch, they can be broken off flush with the face or broken to length as required. Short lengths of pin can be put into the centre of bosses, and will ensure a sound hold for screwing, etc.

As regards the question of core sands and their uses with different types of core-making and machines, conditions are largely governed by circumstances prevailing in routine practice, for any set of conditions which are good for one shop, may be unacceptable for another.

The Ideal Core Sand

Ideal characteristics for core sand are high green bond strength; easy ramming; freedom from "clogging" without the use of parting powder; quick hardening out or air evaporating;

high dry strength to last just long enough for the metal to set around it and then collapse or revert back to its original state, so as to ensure easy fettling; free venting and completely waterproof in a green mould.

Can all these qualities in a core sand be had at one and the same time? Taking them in their order. First, the more putty-like the sand the better it will keep its shape prior to stoving, but it is harder to ram and is unsuitable for jar ramming and impossible to use in a core blower. This type of high green bonded sand usually has good air-drying properties, but for thin-section castings would not burn away enough to allow cooling without the risk of cracking, and these are also hard to clean out from awkward places.

For jar-ramming, a powdery sand is the best, one that will pack evenly with the jolts. This style of sand is usually friable till it is dried and requires packers or packing sand for support on bigger sizes. Porosity or permeability is important too, the harder the core with certain binders the more liable to blow and the greater the need for more artificial venting.

Resistance to mould moisture is also expected where cores are used in green moulds. Oil content is one of the agents in core binders to bring this about.

Sand Binders

There are many binders available—some are recommended for use with dried sea sand, another may be mixed with sea sand as received with a certain amount of oil and the addition of a starch powder. In a foundry without any drying facilities for sea sand, this is a useful and satisfactory type.

In any case, weights and measures are indispensable if uniform results are to be obtained. If 400 lbs. constitutes a batch, then the correct amount of binder should be added each and every time. If a hopper loader is not available, a handy skep such as is shown in Fig. 10, filled twice perhaps, would ensure the correct amount each time.

Core Sand Mixers

Sand mills are not always suitable, and machines with a rubbing or churning action and close mixing are preferable. Most of these machines will mix certain classes of binder into sand so well that the longer it is kept mixing, the more putty-like will the sand become.

Drying temperatures are usually of the order of 300 deg. C., more or less. Recording or indicating clocks are very useful and help toward more consistent results.

Core Stoves

There may still be some of the old-fashioned directly heated fireboxes about, but the efficiency to be had from the hot air circulating type make the others almost obsolete. The hot air type of firebox is a simple concept. Air is forced under and over the fire proper, and temperature is controlled by setting the appropriate dampers. The only criticism, if any, is that the stoking is done by hand and it is recommended to be little and often. The air circulation inside the stove carries away the moisture and gas from the cores. They are very simple to add to many existing types of drying stoves without flue alterations.

It may be of interest to describe a later development which can be added to almost any stove, the automatic stoker; these are a great asset and really do almost run themselves. There is only the hopper to fill and very little to take away in the form of ashes, combustion being so nearly complete. There is also a useful electric mechanism which can be built into this system. It consists of a thermostat to cut in and out at, say, 300 deg. C., as often as required. This feature prevents burnt cores. A time switch is also a useful asset; it can be set to start up and stop at any predetermined time for whatever drying time is allowed. A shear pin is fitted into the drive and any stoppage is indicated by this making contact to ring a bell or put on a light in the watchman's office.

A Question of Design

Before proceeding to the discussion a letter from Mr. A. A. Liardet, Past-President of the Branch, 1922-3-4, was read. He wrote that he was greatly pleased and interested to note the manner in which his old Branch was maintaining its programme in spite of wartime difficulties. Mr. Liardet offered a little friendly criticism on the specimen casting under consideration in the present series of Papers and discussion.

"I am sure you will not mind an ex-President's criticism of the design," he wrote. "I am sorry I cannot join you at the meeting. Is there not a too abrupt change of section? Cannot the boss be tapered at the base as on the lower side, otherwise porosity is almost sure to occur in the spindle hole?"

MR. W. G. THORNTON, referring to Mr. Liardet's comments, said he and the members were delighted to know he was watching the activities of his old Branch with evident interest. In defence of the design of the specimen casting and speaking as one of those who had collaborated in the preparation, he said, that if he and the others concerned had been designing it to make in their own foundry, they would not have designed it quite in the way they did. The sole purpose was to create probable snags and some difficulties which would provide some ground for thought and ingenuity and to find ways and means of overcoming them. Mr. Liardet suggested that there be a more uniform section, and he (Mr. Thornton) did not disagree with him. The reason that the spigot on one side of the casting was made parallel was that it took the valve spring; this was necessary. The taper on the other side behind the valve was to create easy flow for gases.

The meeting agreed with Mr. Thornton, and Mr. H. Forrest suggested that they should write to Mr. Liardet giving him more details in reply and an explanation of the intended design and purposes.

MR. TIMBRELL commented that this point of view had been discussed many times. The design was not easy to alter in important details, and the idea was that such a casting was essential to performance. If foundrymen had more control in the shaping of a difficult casting, the latter would probably be a sound job, but whether their design would be the best, or equal to the requirements, would be another matter. There were so many points of view from the designer's angle, such as easy machining and assembly, reliability in service, resistance to heat, etc., that it must be assumed that they have been considered by draughtsmen when dealing with these awkward castings.

Stove Design

MR. S. W. WISE, speaking in reference to the stove fireboxes described, asked Mr. Timbrell if he thought that the fan and motor fixed as they were shown was satisfactory, and, had he experienced any trouble with the hot gases coming back when the motor was stopped and damaging the windings and insulation.

MR. TIMBRELL said the motors were usually fixed directly over the air box as a complete unit. It was perhaps advantageous and was done in many cases to instal the fan and motor at a convenient place, bearing in mind the extra piping, bends, etc. If the damper to the fan outlet was not closed and the flue dampers were open, hot gases would blow back, with possible damage to the motor. The type of flap indicator shown in the automatic firer prevented this, and it was surprising this was not more widely used, as it also acted as an indicator. The question of the fan being above or below was a point he had not considered, and he doubted if that point much influenced the drying capacity.

MR. WISE said he still thought that, if the motor was above the level of the firebox, there was a tendency to get the hot gases back.

MR. W. PARKER said he had had this system described by Mr. Timbrell running for five years, and had never had trouble with gases damaging the motor. There was a gap between the motor and fan, and also a greaser, which perhaps avoided the possibility of the trouble mentioned.

MR. TIMBRELL said he believed the fan and spindle were in one piece, and the fan casing either attached to the motor housing or at least very close. The intake was usually open at the front and protected by a grill, and, incidentally, in two cases recently this was operated by a louvre to control the intake pull.

MR. PARKER said he failed to see any advantake in putting the fan at any particular place or level, because if there was a back draft, argument ceased.

MR. TIMBRELL pointed out that provision was made to take care of this point and, if the damper was closed when the fan was stopped, there was no possibility of damage. In the case of the flap, this point did not arise.

MR. H. FORREST said further consideration should be given to hot air circulating in the core stove; this was a point not given adequate attention. With regard to the fan and the risk which Mr. Wise had mentioned, he had had a fan motor damaged through placing it on top. It was shifted about 30 ft. away to the most convenient spot for piping, etc., and it had run ever since without further mishap. The trouble in his case was due to the stove bricks communicating the heat to the bearings. He agreed with Mr. Timbrell that the top of the stove was suitable if there was air circulation round it.

Chill-Stick Practice

MR. TIMBRELL mentioned the chill stick through the centre of the casting as a means of producing solidity. He was not convinced that this was necesssary. An improperly baked core will often give a defective casting.

MR. TIMBRELL said his personal belief was that the flues on a stove largely promoted efficiency. It was possible to have a section of a stove almost without heat and excessive heat in another part with improperly laid-out flues. Damper adjustment, when once found, was a factor, and obviously the more rapid the circulation of hot air, the better. If a small pressure can be developed inside the stove, cold pockets have a chance of being dispersed, providing the stove doors did not leak too badly, this could be done by damper adjustment.

As to the use of chill pins, it was surprising the solidity that could be obtained without them when the mixture was of suitable analysis, but the choice of low phosphorus and carbon irons was somewhat limited, and one had to ensure as far as possible soundness in all machined holes. Chill pins allowed a wider tolerance in mixture composition, and, personally, he was an advocate of chills and felt safer with them than without, providing they were used with accuracy in location.

MR. FORREST asked whether chills did not tend to transfer porosity to another position.

MR. TIMBRELL recalled the saying that there was no such thing as an entirely sound casting, and the idea was to move porosity to where it could not be detrimental, or be seen.

MR. FORREST said that, whilst agreeing that much depended on the way the matter was tackled, he still insisted that a chill pin was unnecessary.

Remote Fan and Motor

MR. THORNTON, reverting to the fan and air pressure, said it was policy to put it as near the job as possible, as it saved piping and was generally a neater job. By taking the fan 30 ft. away, would it not mean a bigger fan to avoid loss of pressure? If there was an air gap between the motor bedplate and the stove top, where the heat was, heating up was avoided. For full efficiency the fan should be on top of the job, not away from it.

MR. FORREST said the object of taking the fan 30 ft. away, as was done in his case, was that it was more or less out of the way, and he had not found any less efficiency, and he was happier about it now. Mr. Forrest, referring to the sand question for cores, said he agreed with the author that it was sometimes desirable to have a sand which would air dry, but there were times when it was inconvenient for this to occur, and it can be brought about by adding a small amount of bentonite; this removed stickiness and would still keep the sand putty-like. It increased the dried strength. This tip was useful in summer, when the air drying was quicker.

Foundry Trends

MR. J. BLAKISTON said the discussion was interesting and an important one, because, for one reason, the present trend of foundry industry was to increase core-making, and that trend, through design, was going to persist. In many foundries at present the ratio was a ton of cores to a ton of castings or less, and that meant core-making must be gone into as fully as moulding production had been in the past two decades. Oil sand had had its hey-day. The industry had been through the cereals and bitumastic binders to produce green bond. Fumes would be eliminated by new methods and materials. After the war many munition works would be going on to synthetic resins, which would find their way into the foundries in various forms. Next there would be much less new sea sand used, and a showing of 50 per cent. economy on sand used by employing bentonite or something similar.

Referring to the fireboxes illustrated, Mr. Blakiston said that many existing types of these would become obsolete. Some of the coal-fired ones were liable to give a sooty coating to the moulds and cores. If the specimen casting had to be chilled, he would suggest chilling the part where the spring seats on the spigot.

No Soot Problem

MR. TIMBRELL commented that Mr. Blakiston's remarks about sand sounded revolutionary, and he welcomed any development which would cut down the fumes from drying and casting. At present most core binders evolved disagreeable smoke of an assorted taste and smell, and research into this point was very desirable. In spite of fans and exhaust ducts, they still hung about. The question of the chill on the spigot asked by Mr. Blakiston was interesting. It would have to be of a shape to expand freely, and leave easily, and in addition not be used many times if solidity was to be assured. One advantage of cast-in chills was that they were only used once.

There was no soot arising from the use of automatic stokers, as the combustion was so complete. There was not even any smoke, and the moulds and cores were as clean as could be desired. Most foundrymen had seen the heavy white deposit on cores and moulds dried in coke-fired stoves, yet could it be stated that this was a known disadvantage in any way?

A MEMBER said he would not think of putting chills outside, as it would tend to retard the speed and increase the cost of core-making, as they have to be rammed up or bedded in.

The BRANCH-PRESIDENT (Mr. Fearnside) said he favoured the use of the chill pin as being the simplest method.

MR. PARKER asked whether a centre chill pin would be permissible, remembering its effect during the drilling operation.

MR. TIMBRELL said he thought no difficulty should be experienced during drilling providing there is no white in the fracture. With chills, the composition would influence it. With very low silicon the white edges would prevent easy machining. Even cast at a lowish temperature with the average high-duty iron there should be no difficulty.

III—THE METAL TO BE USED

MR. GEORGE BURGESS, in opening the discussion on the metal to be used, said that the previous discussions (on moulding and core-making) had raised a few points of interest from a metallurgical point of view, one of which was rod-feeding. In view of the size of the casting and the time taken for it to cool, he considered rod-feeding was unnecessary. Again, the nature of the metal which must be used in order to satisfy the specification had a limited freezing range, and was very easily oxidised, and must therefore be poured as quickly as possible. The problem of porosity in the valve spindle guide, which represents the heaviest section part of the casting, was naturally a serious one. It should be possible, however, by the use of suitable metal to produce a solid casting without resorting to the use of chills or denseners. If this was found to be impossible, denseners were preferable to chills in order to avoid trouble in drilling.

Design and Composition

The question arose as to whether the design of runners and feeder heads for this job should be left to the moulder or to the metallurgist. From the point of view of the latter, the runners must be sufficiently large to take care of the relatively poor fluidity of the metal when compared with common foundry iron, and the feeder heads must be large enough to ensure that the heavy centre flange on which they are placed becomes solid before the feeder heads, and thus a supply of liquid metal was available to prevent internal shrinkage. Since it was impossible to put a feeder head directly on to the valve spindle guide, it should be on the centre flange, which is the largest outside section.

Turning to the composition of the metal to be used in this specimen casting, whether the output required was one, 25 or up to 200, Mr. Burgess suggested that in order to obtain test figures comparable with the specification, the casting must be of a good quality close-grained iron. Seen under the microscope, it should consist of small, well-distributed graphite in a matrix of pearlite or sorbite The speaker then showed slides illustrating good and bad metal. To produce such a structure the total carbon content must be kept below 3.3 per cent., and as far as possible maintained between 3.0 and 3.2 per cent. If the total carbon rose much above that figure, the resultant casting would fail on tensile test owing to excessive graphite. If it was below, trouble would be experienced due to high shrinkage, high freezing temperature, short freezing range, poor fluidity, etc.

Silicon and Other Elements

The silicon content of the metal must be adjusted to the minimum amount required to produce a grey machinable casting, since if this amount was exceeded an open-grained and weak casting would be produced and also a greater tendency towards porosity. A suitable figure, he suggested, would be 1.7 to 1.9 per cent. silicon. Greater latitude in silicon limits was made possible by the use of a late silicon addition to the ladle in the form of ferro-silicon. Part of the silicon—0.5 per cent.—could be added in this way, and the total silicon content raised by 0.2 or 0.3 per cent., producing a better machinable casting without loss in physical properties. In a similar way, part of the silicon could be replaced by nickel in the proportion of 3 parts of nickel to one of silicon. The advantage of using nickel in this way was that the difference between the physical test figures on the 0.875 in. dia. test bar and the 1.2 in. dia. test bar was considerably reduced. A useful amount was an addition of 1.5 per cent. nickel with a decrease of 0.5 per cent. silicon. The use of nickel also introduced an element of safety in the regular production of high test figures.

Chromium might also be used in conjunction with nickel, the nickel being used to balance the extra hardness produced by the chromium, which was a powerful carbide stabiliser. He did not, however, recommend the use of chromium, since ferro-chrome was a troublesome alloy to dissolve in the ladle. It did not readily dissolve and might segregate, causing hard spots on the machined surface of the casting. Also, it should be possible to produce the required physical test figures without resorting to the use of chromium. Molybdenum was also usable in connection with nickel. It had a similar action to chromium, but whereas the main action of the latter was as a carbide stabiliser, molybdenum improved the strength of the matrix. Ferro-molybdenum, like ferro-chrome, was troublesome to dissolve, and was better added as previously made high molybdenum pig.

Growth and Maximum Strength

Reference is made in the specification to growth, which is due to the breakdown by oxidation of free and pearlitic cementite into ferrite and graphite with a corresponding increase in volume. This decomposition is arrested by the use of carbide stabilisers, of which the best for this purpose is molybdenum. In an article on the growth of piston ring irons by F. Ballenrath and K. Bungardt, it is stated that "for periods of heating of 700 hrs., the temperature of commencement of growth lies between 400 and 450 deg. C." The composition of the metal being approximately: T.C, 3.8 per cent.; Si, 3.0; Mn, 0.8; P, 0.8; Cr, 0.1 to 0.5, and Mo, 0.3 to 0.4 per cent., and since it was unlikely that the temperature of 400 deg. C. would be reached in actual service by the specimen casting, it did not seem necessary to take steps to produce special iron to prevent this growth.

Maximum strength is obtained when the metal contained 0.3 to 0.35 per cent. phosphorus, and good physical test figures could be obtained with up to 0.6 per cent. P, but fell away very rapidly if taken beyond this figure. If this phosphorus content were used in practice, however, it was very likely that trouble would be experienced due to porosity in heavy sections, especially in the valve spindle guide which, from the specification, required to be drilled and ground and must be perfectly sound. Also trouble would be experienced from liquid shrinkage defects, the casting probably exhibiting a shrinkage cavity in the corner formed by the centre boss and the centre flange. In order to minimise these tendencies, the phosphorus content should be kept about 0.15 per cent., with 0.20 per cent. as the maximum.

In wartime, it may be desirable, owing to the necessity for conserving hematite pig-irons, to attempt to make the casting in relatively high phosphorus cast iron. If this was found to be necessary 0.6 per cent. phosphorus should be regarded as the upper limit. The total carbon content of the iron should be reduced by 0.1 per cent. for every rise of 0.3 per cent. P; the temperature of melting and casting should be raised, and the size of runners and risers increased. In order to reduce the increased tendency of the casting to chill, the silicon content of the iron should be raised, or if alloy iron were used, the amount of alloying agent should be increased with slightly more nickel to balance. A better way of utilising high phosphorus pig-iron would be to use it for making low carbon pig-iron or refined iron by mixing with steel scrap, and then re-melting this for making the casting. In this way 30 to 40 per cent. high phosphorus pig mixed with 60 to 70 per cent. steel scrap would produce a low carbon iron with 0.4 to 0.5 per cent. phosphorus. The S content of the iron should be as low as possible—0.12 per cent. maximum; and the Mn content sufficient to balance this, say, 0.80 to 1.0 per cent.

Melting Practice

For large or small quantity production the metal would be cupola-melted, and special care was necessary to ensure uniformity of composition and adequate tapping temperature. Existing plant governed the size of the cupola, but if possible this should not be large if only a small quantity of castings was required, because a small number of large-weight charges are more difficult to separate from charges of a different composition than a number of small charges. In any case, if large charges were used, these should be poured from two or more small ladles holding a maximum of 5 to 6 cwts. This enabled the moulds to be cast quickly without loss in temperature, two or more moulds being cast at the same time. If large ladles were used, the metal would probably be too cold to be of any use before the ladle was three-quarters empty.

The height of the bed-coke depended on the diameter of the cupola, but it should not be less than 36 in. above the centre line of the tuyeres, and for small cupolas higher than this, in order to produce the necessary high temperature. The charge coke should be sufficient to replenish the bed after each charge was melted. This amount should provide a 4 to 6 in. layer of coke in the furnace, extra charge coke being used if large quantities of steel scrap were used on the charge. The period of the blow used for these special charges was important owing to the danger of contamination with material of another composition. The best place was at the end of the blow, separated from previous charges by one or two charges of metal of a composition similar to that of the special metal. The next best position was at the beginning, when the same separating charges should be used to follow the special charges. This was important, especially when the normal run of irons used were high phosphorus and therefore quick melting.

It was advisable to charge first one or two charges of metal which were not required for important jobs, since the first charges in a day's blow were always the coldest and contained the largest amount of sulphur. The refined pig-irons previously mentioned could be conveniently produced in these charges. All charge constituents, including coke and limestone, must be weighed. The amount of limestone used should be adequate but not excessive, and of the order of 3½ lbs. per 100 lbs. of metal. This should be distributed evenly over the surface of the coke charge in the furnace before charging the metal, which should be charged in reverse order of melting—that is, steel first, scrap last. After the metal left the furnace, every care should be taken to prevent loss of heat. The ladles before use should be clean, if possible freshly lined; thoroughly dried and at red heat. They should be semi-covered, as the most serious heat loss was from the surface of the metal, due to radiation and drafts. Once the metal was in the ladle it should be poured into the moulds as quickly as possible. Cold alloy additions to the ladle also cooled the metal rapidly, and should be cut down to a minimum. Tea-pot ladles kept the metal free from slag, etc.

Metal Mixtures

It would seem rather wasteful to put on a special metal charge for a one-off job which involved the trouble of separating this from the rest of the charges. Iron such as was used for ordinary jobbing work would not, however, fulfil the physical test figures demanded by the specification, and it was doubtful whether ladle additions would produce the required physical properties. Even if these were produced it would not necessarily follow that the casting would be sound. Some attempt, therefore, must be made to alter the composition of the base metal previous to melting by the addition of a suitable percentage of steel scrap, ferro-manganese, ferro-silicon, etc., to bring it somewhere near the compositions already set out. In quantity production—200 off upwards—the use of special refined irons was justified, and was preferable to the use of large quantities of steel scrap in order to produce the required low total carbon content. Pig-irons with a tendency to large graphite such as hematite should not be used, as they tended to retain this characteristic even after passage through the cupola. Steel scrap might be used up to about 30 per cent. in the first mixture, but it should be possible to cut this down by using return scrap—runners, risers, machine-shop scrap, etc.—in subsequent mixtures. The segregation and use of these returns was most important from the point of view of economy and uniformity. The use of high steel mixtures tended towards lack of uniformity in carbon content, high sulphur pick-up, shrinkage troubles, etc. Also, the composition of all the constituents forming a charge should be as near the finished composition as possible after allowing for changes during melting. The manganese content of the iron should be adjusted to the required level by the addition of ferro-manganese to the charge before melting.

Metal Control

In quantity production of the specimen casting, frequent checks should be taken on the composition and structure of the metals used. This could be done by the usual methods of chemical analysis, micro-structure and physical test figures. Unfortunately, the results of these tests were only obtainable some time after the castings were made, and if these turned out wrongly, the only thing to do was to scrap the castings. Some kind of quick check, therefore, was required at the furnace before commencing to fill the moulds. This could easily be done by the use of small wedge test-pieces cast from every tap, quenched in water, broken, and the fracture examined. The amount of chill on the test-piece should then be measured, and for this particular casting, from the analysis given, would be 7 or 8 mm. This method of testing was particularly useful when using late silicon additions or nickel additions to the ladle, the amount of addition used being adjusted to produce the required amount of chill on the test-piece, thus eliminating variations in composition due to furnace conditions and in pig-iron weighing, etc.

Silicon Control

MR. JAMES TIMBRELL, SENR., said it might be difficult for the ordinary jobbing foundryman to carry out some of the ideals Mr. Burgess had mentioned, but the suggestions were very good and the effort would go far towards making a good job. He endorsed the utility of the wedge test, even though the small foundry owner would find interpretation difficult. Using charges of iron and steel scrap, or re-melt, to reduce the carbon was a good method, but it involved rather a high cost, though there was little alternative if low phosphorus and low carbon irons were desired. Could Mr. Burgess suggest any way of definitely controlling silicon ladle additions? What would be the loss from a 5 per cent. ferro-silicon ladle addition? What temperature allowance should be made to compensate for ladle losses?

MR. BURGESS, in reply, said the difficulty of the wedge tests was admitted, but to produce this casting regularly it was necessary to institute such a strict control. It was not so difficult to get the proper irons, as there was quite a selection now on the market. The wedge test should be used when silicon additions were made, and any later additions made would involve about 20 to 25 per cent. loss. It would reduce the temperature in large quantities, but on this job it would not be excessive. The pouring temperature should range from 1,200 to 1,400 deg. C., but it might reach 1,450 or 1,500 deg. C. It was doubtful whether success would be achieved under that temperature even though it may look somewhat high. There was the oxidation to consider.

Base Metal Preparation

In answer to a member, Mr. Burgess said when he mentioned 60 to 70 per cent. steel scrap for making a refined pig-iron he was referring to the blending with high phosphorus pig-irons. The amount of silicon in the pig would vary and be controlled by ferro-silicon additions.

Mr. Timbrell suggested that alloy additions gave better results when furnace melted than when made as ladle additions, as a more homogeneous composition resulted.

Mr. Burgess agreed that such was possible, but pointed out that an initial attempt should be made to produce this casting without the use of any additions at all except ferro-silicon.

Mr. S. Carter said Mr. Burgess spoke of the high physical properties of a 0.35 per cent. phosphorus iron, and suggested that a 0.1 or 0.2 per cent. phosphorus iron would not be so good. Could he elaborate this?

Mr. Burgess said that it had been proved by many experiments in the past year or two that 0.3 to 0.35 per cent. P have definitely given the best results. He could not give a clearer definition at the moment as to why that occurred.

Small Sectioned Steel Scrap Detrimental

Mr. S. Wade asked why in cupola practice small sectioned steel scrap was deemed to be detrimental?

Mr. Burgess suggested that the supposed trouble was due to the oxidation of the steel in passing through the furnace, and he recommended that steel additions should be not below, say, half an inch thick.

In reply to a member, Mr. Burgess said in the case of this specification, aluminium flux would have a pronounced tendency to produce large graphite, and he would not advocate its use in this type of pressure casting.

Choice of Composition and Chill Elimination

A member asked whether on the composition recommended it was possible to get good test results without using a chill either on the outside or the inside of the job?

Mr. Burgess said it was a matter for trial, and if it was found inadequate then denseners should be used.

Mr. H. Forrest said Mr. Burgess's point was that it was impossible to enumerate rules for making these castings without taking into account the many factors involved, and it was not easy to draw up a specification to cover all these points. If one could not overcome the difficulty by compositional control then use denseners, but if the iron gave the requisite properties without the use of chills, it was preferable. When dealing with a 200-off job it became a specialised job, and the foundryman was driven to using an iron of suitable composition, based on phosphorus irons available mixed with ferro-silicon or steel, or alternatively with 10 per cent. silicon pig-iron. There will be some sulphur pick-up on re-melting, but that can be neutralised by the use of a soda ash treatment in the ladle. The foundries who are making the 25-off are at the greatest disadvantage because they have not much margin for wasters if the practice had been wrong. The only way to tackle the job on those lines was to melt down a quantity of the steel and the high phosphorus iron and get a so-called refined iron.

Mr. Forrest suggested test wedges be poured from a small ladle, and knocked out whilst red hot and left to cool until black and quenched. The wedges could be prepared within a minute, and showed visible evidence of the chilling of the iron and whether it was an open or close grain.

Graphite Control

Mr. H. Balme said he was interested in the question of the correct distribution of the graphite. Could this be produced without any special alloy addition? On the matter of efficiency of the addition of alloys there were diverse views. He had made alloy additions at the spout and, when done carefully, he had had very good results, yielding a mixture which, if not perfect, at best approached perfection. On the matter of thin sectioned steel additions—quite often received nowadays—he felt that that was an argument in favour of the use of refined pig-iron. Sections of 5/8ths, etc., were more suitable than cubes of 2 in. square.

Mr. Burgess, in reply to Mr. Balme's first question, said he thought this should be possible. The higher the carbon the higher the graphite and the more of it. In regard to alloy additions at the spout, personally he would add all at the spout except ferro-manganese, if used. As to the steel scrap, he was fully in favour of using a 3/8ths or half inch plate if it was in lengths of, say, 5 in. or so across.

Mr. J. Stott said in regard to refining of graphite, recent American research came to the conclusion that graphite was not affected in size by the additions, but merely by the cooling.

Mr. Burgess agreed that the main influence on the graphite is the rate of cooling.

Mr. S. W. Wise said Mr. Burgess had given his experience based on conditions in which every possible control was enforced, but in many of the foundries 1,450 to 1,500 deg. C. was a rather high temperature to attain, and many of them, he felt, would like to know how they could get it. As to steel scrap, he doubted if there was any risk in using small scrap. He used much of it for certain work in the last war period and never had any trouble. He did not favour aluminium additions.

Mr. Burgess said the high temperature involved, *inter alia,* blast volume control. He agreed with Mr. Wise as to aluminium additions.

The Branch-President said in the course of discussions on the production of this specimen casting from the foundry point of view there had been many references to both internal and external chills. Mr. Burgess apparently did not favour this method much, yet as a safeguard one would be justified in using some chilling method around the inside of the casting, especially in the 25-off job.

MR. A. W. WALKER asked whether Mr. Burgess would recommend an addition of calcium silicide.

MR. BURGESS said it could be used to make a casting grey if it tended to be white.

Metal and Riser Elimination

In reply to a member who asked whether the metallurgist could make up a metal which would do away with feeder heads and therefore avoid a good many of the difficulties arising out of the use of feeder heads, MR. BURGESS said he did not think it likely that a casting could be made to meet the requirements of this specification without the use of a feeder head, and moreover he would advocate that the feeder head should be large

The BRANCH-PRESIDENT pointed out that with a large variation of section one could not possibly use any one type of iron for any and every job, and it was necessary to use methods, even an old-fashioned one like chills, rather than experiment with a fancy iron at risk of losing the job. That, at any rate, will be the feeling of the average foundryman who cannot afford wasters.

MR. BURGESS said his point was that it would be difficult to use a chill on a job like this to get at the seat of the trouble.

MR. S. CARTER said there seemed to be an impression in the meeting that this would be a very difficult job to make, but that was not so. It could be produced without any risers at all, though he favoured the use of chills.

MR. BURGESS said his object was to do without chills.

A MEMBER suggested that in the interests of soundness a pressure head should be used instead of a taper head.

High-Temperature Melting

MR. TIMBRELL, referring to the 1,450 to 1,500 deg. C. temperature, which he considered rather high, remarked that Mr. Burgess would seem to be very fortunate in his light scrap supplies, from which one can get a very high temperature, but it was not so easy with heavy scrap; yet one had to get rid of the heavy scrap somehow or somewhere.

MR. BURGESS agreed that foundries had to use up the heavy scrap, but why not employ it on some job that did not require the high temperature?

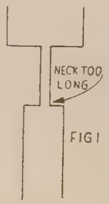
IV—POTENTIAL DEFECTS

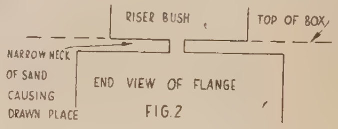
In introducing the discussion on the potential defects to be found in the specimen casting, MR. H. BALME considered the subject under three headings: (1) Moulding faults, (2) coremaking, and (3) metal used.

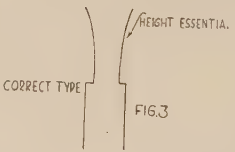
Moulding Faults

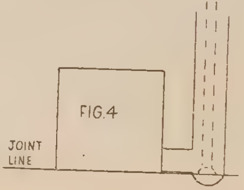
It is self-evident that the sand, box parts and pattern must be entirely adequate for the job in hand. In the case of a one-off job, it would probably be given to a side bay moulder, who would use sand which would be tough, heavily milled and highly bonded. The possible defects would include:—(1) Scab against the runners; (2) sand holes arising from scab, probably in a position to be machined; (3) drawn places, *i.e.*, externally at the corners and particularly against the flange, due to gas pressure. These defects are also likely to occur from other causes, such as over-wet sand, whilst drawn places —due to gas pressure—may result from excessive coal-dust content. Such defects are also likely to occur in quantity production, if similar sand was used, with the added defect of misshapen castings in the case of jolt-machine-made moulds, due to the poor packing qualities of such a sand. The following remedies are suggested:—The use of a sand of high permeability, and reasonable moisture content, say 5 per cent. for loose pattern work and 3 per cent. for machine moulding.

For the running of the casting, a dirt trap is an essential. Rod feeding being out of the question, some form of self-feeding is called for, and Figs. 1 and 2 show potential mistakes, whilst Figs. 3 and 4 illustrate good practice.









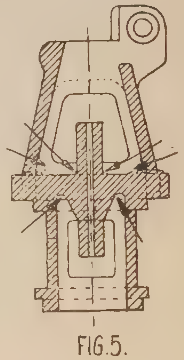


FIG.5.

Core-making

The prime requisite of cores is that they must be true to shape, for ill-fitting ones cause thick and thin sections in the castings, where uniformity is essential. This applies especially to the shape and position of the spigot boss on which the valve operates when working. Mr. J. Timbrell, Senr., stressed the necessity for avoiding coreboxes of too fragile a construction, and indicated the potential defects arising therefrom. Outstanding amongst potential defects, however, are those due to insufficiently dried cores, giving rise to gas pressure, and the creation of hot spots. The creation of these is indicated in Fig. 5. The importance of well-dried cores was shown by an experiment with an apparently adequately dried core having a permeability factor of 136, which evolved 13.5 ml. of gas per gramme of core at N.T.P. This core, after redrying at the correct temperature, had its permeability improved to 274, and the gas evolution was reduced to 1.5 ml.

Where chills are used with cores, the following defects may occur:—(1) Gas holes resulting from poor chill preparation; (2) difficulty of securing in the cores; and (3) blows from the joints between chills in two half-cores.

Metal Used

The composition, as outlined by Mr. G. Burgess, is characterised by low total carbon; medium silicon (1.7 to 1.8 per cent.); fairly high manganese and low sulphur and phosphorus. The objects are to ensure finely distributed graphite; close-grained, yet machinable, metal; and a reasonable freedom from phosphide segregations. No criticism is offered and alternative composition suggested, but it is germane to point out the potential defects of such a metal ready for casting. Even charging of the cupola is assumed and, if small and thin steel be used, it should form the last material of the charge, whilst heavy steel scrap should be the first. Considerably more coke will be required than for high phosphorus mixes, because (1) the necessity for the provision of free carbon to be absorbed by the steel, involving a reducing atmosphere; and (2) to provide a compensation for the inefficient production of heat under reducing-atmosphere conditions. The blast must be "soft" to ensure the reducing-atmosphere condition, and it should be appreciated that repeatedly inducing off-on conditions results in excessive carbon pick-up and a very irregular melting rate. This latter factor is important because a controlled melting rate is essential to ensure a true mix uncontaminated by the preceding or the following charges. It is worthy of note that it might be difficult to use up the over metal, as medium-sectioned work might give trouble in the machine shop. It would seem advisable not to use all the metal melted. The metal might be "dull" before the last mould is cast, whilst, when using hand shanks—the last of which to be used should be especially well dried—there will be a difference of composition, attaining a maximum amplitude in the first and last to be used.

Use of Risers and Runners

The BRANCH-PRESIDENT (Mr. W. Fearnside) said they were indebted to Mr. Balme for pointing out what were undoubtedly possible defects which would be liable to arise in any foundry producing this specimen casting on the drawings and specifications as submitted.

MR. W. G. THORNTON agreed with Mr. Balme as to the tapered riser on top of the flange, as the only real method of feeding this job. An alternative was to place the runner on the top of the round flange and tap.

MR. BALME said that if he, personally, were making this casting, he could make it quite sound without using a riser. Moreover, the riser might be one of the causes of a potential defect.

MR. THORNTON said that under similar conditions he would use a pencil runner and eliminate the riser.

Running Conditions

MR. H. FORREST pointed out that those used to dealing with a material with a short feeding range knew what to expect and took steps to overcome the resulting defects very quickly, but for those habitually handling high phosphorus iron it comes rather as a shock to find half the metal has been taken from the ladle and the rest is useless. It was essential to keep in mind that this metal might have a very short freezing range and have everything arranged so that the metal could be run off as quickly as possible. He disagreed with Mr. Thornton's idea that pencil runners would be suitable to the type of metal advocated in this case. On the question of risers, also, there was only a short neck of metal to reach the centre boss, and where was the liquid feed to take place so necessary for the centre, because it had later to be drilled with a very small hole? It was essential to provide the metal with some liquid feed.

MR. THORNTON said he still maintained that a pencil runner would serve if the job was cast as hot as possible.

MR. FORREST pointed out that the chill in the centre had to be bored out. Therefore, to allow $\frac{1}{16}$ in.—which was cutting it very fine considering it is a fairly long hole—means that any chill would have to be small. If that chill bends or is not perfectly round as a casting before it is introduced, there will be some "wandering" of the drill.

Alloyed Iron Suggestion

MR. NICHOLLS, referring to the composition of the metal, said the specification called for an 18-ton per sq. in. iron. One would expect with this design to get numerous gas-holes. It has been stated that the metal used should be a low carbon iron and naturally had a shorter freezing range, and therefore the gases were more likely to be trapped. He suggested using a composition of about 3.3 per cent. carbon, and if there was no drawback on grounds of cost, he would use a nickel-chrome iron to allow the gases more time to escape. Personally, he would make the casting from the last charge to ensure the correct composition. The job should be run as quickly as possible in the hottest metal, which would guarantee a reasonable low carbon content of about 3 per cent.

MR. BALME, agreeing, said the method outlined would be the ideal one, but in many a foundry it would probably be out of the question in practice. As to topping up the riser, no doubt the ideal method was to top up if it could be adjusted correctly, but personal experience was that it was not easy to get it exactly at the right height, and that was where one was liable to get a hot spot.

MR. NICHOLLS said the liquid was bound to find its own level, and, if this feeder was controlled, he did not think a great deal of metal would be forced back into the casting.

MR. BALME said Mr. Nicholls had suggested as suitable for this type of job a nickel-chrome mixing, but that alloy would have to be added at the spout, and that was not easy if it was not being used on other jobs at the same time.

MR. NICHOLLS said that, naturally, if a nickel iron was used, it would necessitate the silicon being reduced by a corresponding percentage. The object in suggesting nickel was that it would give a better chance to eliminate the gas-holes by allowing a greater time for the gases to escape. He would add the nickel at the spout. If there was any question of the metal being dulled, this could be overcome by varying the composition of the charge and making the necessary additions of silicon, etc., so that the temperature of the metal would not suffer at all. In answer to a remark by Mr. George Burgess on the subject of alloys, Mr. Nicholls said the fact that nickel was a graphitiser should help to maintain the feed.

MR. FORREST said he could hardly agree with the last speaker's implication as to increased fluidity of nickel iron. Personal experience was to the contrary, and that it tended to shorten the freezing range and caused a lack of fluidity. He doubted very much whether it would materially help the temperature of the metal in the ladle, though he agreed to a great extent that one could use pencil runners and make a successful casting that would normally be run fairly fast. In a previous discussion the question of adding nickel was referred to, and whilst not everybody might be in a position to add nickel-chromium or molybdenum to a one-off job, it was agreed that it would be useful to add molybdenum to a one-off job, though it might not be worth while to use chromium in such a case. It was not suggested that nickel would increase the fluidity or be a cure for shrinkage.

A MEMBER said that, assuming a good iron and hot melting, with the metal running reasonably fluid and casting quickly, no trouble should be experienced. If it was cast dull—if it solidified at one side—there would be spongy places. He would certainly eliminate the riser and let the metal take care of itself.

MR. J. BLAKISTON said the lectures in this series had been more than valuable, but it is perhaps a little unfortunate, to complete all points of view, that nobody representing consumer interests had participated. Another matter on which the series of lectures had not touched was the fettling—an aspect which also affected the consumer.

MR. J. POTTER said he felt the most likely trouble in this particular case was perhaps in the centre boss. The flange was very thin and that metal was liable to set first. How were they going to feed that centre boss really satisfactorily? The practical way, he thought, was by having a thicker centre or some very small risers. One trouble which had not been mentioned was that of getting the job pressure-tight. They would not, he believed, get the boss pressure-tight unless they used a thicker centre and, to his mind, only an outside chill in the core would render the metal sound in the centre.

American Synthetic Sand Practice

DISCUSSION ON PAPER No. 730*

The Paper was introduced for discussion by Mr. W. B. Parkes.

Mr. H. J. Beck (Branch-President), in opening the discussion, congratulated Mr. Parkes on the lucid manner in which he had presented Mr. Dunbeck's Paper, and said he had been using synthetic sand with pronounced success for a considerable time, but there was one point on which he would like a little more enlightenment. When making blackheart malleable castings in sand bonded with bentonite, he had noticed there was a tendency for the castings to develop tears or hot surface cracks in irregular sections. One particular casting which gave some trouble weighed approximately 40 lbs. These defects had never been experienced when producing any of these castings in naturally bonded sand using the same method of gating and feeding. The defects had been overcome by the addition of " ties " and the increasing of fillets where radius permitted. Could Mr. Parkes give any reason why these defects should occur when using synthetic sand?

Influence of Atmosphere

Mr. H. Bunting thought members should look at this Paper not from British practice, but rather American, and this again not only from the foundry standpoint but also from atmospheric conditions which in America are far different from those in this country. American foundries were more mechanised than those in this country, and synthetic sand is far more useful for mechanised plants than it is for ordinary work. Mr. Parkes remarked that it was difficult to ram up, and when one considered that the majority of the foundries in this country were on jobbing work more so than mechanised plants, the position was not so favourable.

Synthetic sand was not altogether new. He had some experience with it about 40 years ago, with a result that the whole of the castings made were scrapped, together with the system. Probably if the same firm were to try it again using the greater knowledge that existed to-day, they would make a better job of it. One of the factors against it in this country was that there was a different moisture content in the atmosphere which one had to consider. The moisture content has to be controlled more so with a synthetic sand than it does with natural sand. One had to consider carefully the grain size, and without proper control it was an impossibility to carry out successfully.

Mr. F. J. Butters asked whether naturally-bonded sands were as abundant in America and as good in quality as they were in England.

Mr. Parkes stated that as far as he could judge from information given both by American foundrymen and colleagues who had travelled extensively in America, deposits of naturally-bonded sand were at least equal to those obtainable in this country.

The Two Bentonites

Mr. Butters, quoting from Mr. Dunbeck's Paper wherein it was stated that " the base sand may be a bonded sand, a low-bonded sand or an unbonded sand; an unbonded sand is preferable since the clay in naturally-bonded sand is usually neither efficient nor refractory," said that he did not agree with this. His foundry used a local sand which was unrivalled for light castings.

The Paper alluded to buckles and scabs, and these defects appeared in maximum development in the cope of the mould. This was also contrary to personal experiences. There was also some reference to malleable, and the statement was made that " kaolinite clays have adequate hot strength for any job when properly handled. It may also indicate the source of some cracked castings in the malleable industry since an overtempered batch of sand has far higher hot strength than the same sand properly tempered."

He, Mr. Butters, thought there was a danger of " hot tears " or fractures occurring in some designs of malleable castings, if a " high hot-strength " sand mixture was used, as their vulnerability to this type of defect was probably due to the natural characteristics of the metal, which was white in the " as-cast " condition, and had a double contraction.

Nearby this quotation there was reference to bentonite. He had used a little bentonite, and there was a potential source of trouble unless the bags were labelled Southern bentonite or Western bentonite, as there was a considerable difference in the strengths. Towards the end of the Paper it is stated that " synthetic sands are almost always more refractory, and give higher sintering points than naturally-bonded sands. This results in better stripping and lower cleaning costs."

When he (the speaker) was trying bentonite out about 18 months ago, he examined its results from several angles. It was a success in the light castings shops, but from a heavy castings standpoint it was an absolute failure. He used the same type of sand with the same addition. The castings were flywheels, about 2 ft. in diameter and possibly 2 cwts. in weight, the maximum thickness on the rim being about 4 in.

The castings carried a very rough finish, due to the sand being fused on the surface. He would like Mr. Parkes to explain why bentonite failed so miserably on these heavy castings. He still used bentonite, but he never had the same stripping qualities in heavy work as was the case by using Kidderminster sands. These sands have excellent qualities from a stripping standpoint. The coal dust is also another problem. Finally he asked Mr. Parkes as to what he considered to be the best substitute for bentonite.

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* East Midlands Branch discussion of 1941 A.F.A. Exchange Paper; see Proc. Vol. XXXIV. p. 17.

MR. S. BECK said he had carried out a few tests using Fulbond in place of bentonite, and from these it appears to be a satisfactory substitute, but one thing he had noticed was that the sand stuck to the pattern very badly. He wondered if there was anything in the chemical composition to account for this, as this would be rather a serious matter if one changed over to Fulbond entirely, particularly where metal patterns were usually used.

Selection of Materials

Under the heading "Base Sands," the author stated: "A synthetic sand may be made from all new unbonded sand and clay, or from naturally-bonded sand and clay or from combinations of these materials, and that there is a certain loss of sand on the casting which is replaced by daily additions of sand and which will eventually compose the entire heap, and therefore the final result will be the same whether a start is made with a completely new synthetic mix or not."

Some time was bound to elapse before the base sand constituted the bulk of the mixture. Was one to work off an inferior mixture until this final result took place? If one were to use naturally-bonded sand with silica sand it would mean the smaller grains of naturally-bonded sand falling between the larger grains of silica sand and a mixture of very low permeability would result. There would also be the question of bond. Would not there be a bad distribution of the bentonite due to the presence of the natural bond? He had achieved great success with synthetic sand, and believed this had been due mainly to the control, and he was of the firm opinion that to allow the naturally-bonded sand to mix with synthetic would mean that much of this control would disappear.

He had been very interested in the tables of hot strength in combinations of bond clays, and agreed it was a problem that needed attention. He had recently used a smaller quantity of bentonite than usual and had made up the balance with another type of bonding clay, and this mixture had been used with a certain degree of success on jobs where tears had occurred.

When choosing bonding clays, an important point to remember was its staying power or durability. A sand with certain bonding materials in it might have a very high bonding strength to start rapidly, and the sand would need reconditioning more often, making it uneconomical for use.

Would Mr. Parkes consider a desilting apparatus an essential part in the preparation of sands? The author spoke of having a percentage of fines in sand. Was this necessary on all classes of work? If so, what would Mr. Parkes consider a suitable percentage as a basis. With the silica sand coming in contact with the metal, it is bound to have a wearing action on the silica sand, making a higher percentage of fines, and thereby lowering the permeability.

About six months ago he found the permeability getting low and at the time he was adding 20 per cent. of new silica sand, so he increased it to 50 per cent. for two weeks to bring the permeability to a satisfactory level, and from that time he had had no further trouble.

Burnt Core Sand

The experiments he had carried out using burnt core sand had been highly satisfactory, but the difficulty was that the largest amount of castings produced were made in naturally-bonded sand and, when the casting was taken out of the sand, the burnt core dropped into the sand, and to pick it out would mean getting a certain amount of natural bonding sand, making it unsuitable for use in synthetic sand. Another difficulty experienced was that a rather large amount of the core was not quite burnt, leaving a very hard lump of core sand. What method did Mr. Parkes recommend for breaking up these lumps. Would there be a tendency for the sand grains to be crushed in the breaking up in heavy roller mills?

Finally, under the heading of "Sands," it had been mentioned that a foundry may be using a naturally bonded sand with a moisture of 7 per cent. and a permeability of 90. Was there an actual case of a foundry using sand of this nature? If so, could the members have more information on this, as he felt sure his foundry would be interested?

Too Easy?

MR. J. C. HALLAMORE said that, when one read through the Paper, it almost appeared that synthetic sand was the cure for all foundry sand problems. Reading from the Paper, under the heading "Mixing Mills," one only had to have a mixture in any proportions of any sand, such as used moulding sand, burnt core sand, new silica sand; also mentioned were gangway sweepings or any sand that can be collected around the foundry. Clay was then added by almost any method, and one had the required sand. Mr. Bunting had stated that synthetic sand was used mostly by mechanised foundries. Were there any American jobbing foundries using it? Mr. Parkes had stated that one disadvantage was the quick drying-out of the sand; yet one paragraph in the Paper said that the sand was often made by the night shift, so as not to hinder daytime production. Was this sand stored in a special hopper, or how was it dealt with? One objection to additions of new sand to restore strength was the resulting surplus by additions of used core sand, etc. Was not the same surplus obtained with synthetic sand?

Author's Reply

Replying to Mr. Beck, MR. PARKES said that in the Paper it was suggested that, where trouble was experienced through cracking of castings, a bonding clay with a lower dry strength should be used, Southern bentonite being recommended, especially for malleable castings. The bentonite which had been in use in this country for some time, and which, presumably, was the material used by Mr. Beck, was Western bentonite, which had a higher dry strength at all temperatures up to 1,000 deg. C. than any other single clay. Improvement could be expected from the substitution of a clay with a lower dry strength, and quite a number were available in this country.

He agreed with Mr. Bunting as to the difficulties to be expected when first using a synthetic sand in a jobbing foundry owing to the low moisture range over which the sand could be used, but thought that atmospheric conditions were more favourable here than in America. The difficulty was that the sand dried out before it could be used, and in the summer, when the trouble was at its worst, the American climate was both hotter and drier than English, and the loss of moisture would be more rapid.

The Colour Test

Replying to Mr. Butters, MR. PARKES said that there were several types of scabs, but that the type described as a buckle occurred usually in the cope, the whole of the top surface of the mould collapsing in very bad cases. The scabs which Mr. Butters had found on the drag may have been due to some other cause. Little trouble would be experienced in differentiating between Western and Southern bentonites in a foundry in which both were used. In the first place, the containers would be labelled, and the only Southern bentonite he had seen in this country was sold under a trade name, whilst in case of doubt the appearance of the two materials was very different, Western bentonite being white and Southern bentonite greyish brown.

Relative Refractoriness

So far as refractoriness was concerned, all the silica sands used for preparing synthetic sands in this country were more refractory than red Bunter sands, such as those from Mansfield and Kidderminster, which contain up to 25 per cent. of fusible felspars. The rough surface on the heavy castings might have been due to the penetration of metal into the comparatively large pores of the synthetic sand, especially if the same amount of coal dust had been used in both cases. With sands of high permeability from which gas could escape very easily, the minimum amount of coal dust required to give a smooth blue skin would usually be higher than with close sands.

With regard to alternatives to bentonite, Colbond had been in use with success for a long time, but supplies were not unlimited, and the most promising of the new materials was fuller's earth, sold by the Fuller's Earth Union as Fulbond No. 1 and Fulbond No. 2. Comparing these with bentonite it would be necessary to use 6 per cent. Fulbond No. 1 to replace 5 per cent. bentonite to obtain the same green strength, and the dry strength would be about half that of bentonite, in which it resembles the clay present in red sands such as Mansfield. No. 2 resembled No. 1 in green bonding power but was nearly equal to bentonite in dry strength.

Fulbond had been tried out on a fairly large scale in a number of steelworks with satisfactory results and it was hoped that the new plants in course of erection would be able to satisfy the whole of the demand for bonding clays.

Sand-to-Pattern Adherence

MR. PARKES, replying to Mr. Beck, said that he had had no personal experience with Fulbond in the foundry, but had not heard of the trouble mentioned by him. The most frequent cause of sand sticking to the pattern was high moisture content, and when changing from one clay to another it was important to remember that different clays might require different amounts of water to produce a material which could be moulded. This point was mentioned several times in the Paper, and in Table I, the different types of clay were placed in order as regards the amount of moisture required by each type. Even where clays of similar mineral composition were concerned, differences would occur and it was quite possible that a sand bonded with Fulbond would give best results at a moisture content somewhat different from that required when the bond used was bentonite.

With reference to durability, it was stated in the Paper that kaolinite clays are better than montmorillonite clays, although work done some years ago in this country seemed to indicate that this might not apply to all kaolinite clays. The most satisfactory practical method of measuring the relative durability of clays which were being used was to compare the amounts required to keep the strength of the sand constant under standard conditions, and so far as could be seen from the short time tests available, there was little difference between Fulbond and bentonite.

When changing over a system from a close natural sand to a much more open synthetic sand, the change could be made gradually by altering the new additions or rapidly by replacing the old sand almost entirely. In the first case, as was pointed out by Mr. Beck, the improvement in permeability would be slow, and in practice it was almost impossible to raise the permeability of a sand by 50 per cent. by means of new sand additions until those additions formed more than half of the mixture. The same result could be obtained by removing half the sand in the system and making up with the new open sand, but in this case there would be a sudden change in such properties as the range of moisture content over which the sand could be worked, and some difficulties in moulding might be experienced. Unless, therefore, there was urgent need to raise the permeability of the sand by a considerable amount, it would be better to make the change slowly.

Desilters

Occasionally desilters were used with synthetic sands prepared by adding a clay to a silica sand, but they were usually unnecessary as most of the latter available in this country are so permeable that the presence of some fines was desirable to prevent surface buckles, to increase the moisture range and to improve finish. Cracking of sand grains in moulds did not appear to occur to any serious extent, especially in the presence of coal dust.

When it was desired to use the sand from oil-sand cores to make up the synthetic sand system, both core sand and moulding sand should be prepared from the same silica sand, in which case any core sand disintegrated by heat would fall into the system at the shake-out and give results equal to those obtained from new sand. Large fragments of core from the core knock-out could be broken down by grinding, but the rollers should be raised a little from the pan to avoid crushing of grains when the mill is partly empty and aggregates should be sieved out of the ground material before it was used. It would be very difficult to recover disintegrated core sand from another sand system using a close natural moulding sand without including some of the latter, which would reduce permeability, but the larger fragments could be recovered.

Natural sands with a permeability of 90 and sufficient bond for moulding had not been found in quantity in this country, but they have been worked on the Continent for many years. In particular, French and Belgian yellow and red sands were found with permeability ranging from 90 to 200 and strength from 10 to 20 lbs. per sq. in., and before the introduction of synthetic sands were used for the majority of the steel castings made in green sand in this country.

Clay-Adding Methods

MR. PARKES said he could not agree with Mr. Hallamore's description of the method of adding clay to a synthetic sand system, for while it was quite true that taking a number of different foundries it might be found that in one case the addition was made before the shake-out and in another at the mill, the amount used was carefully controlled, and the place chosen was the one which gave the best results for that particular plant. Used moulding sand represented the bulk of nearly all synthetic sand systems, but in time the grain size and distribution of the used sand became the same as that of the new sand added, and a new sand was chosen which would give the properties desired. In many foundries the new sand was replaced by material recovered from oil-sand cores, and to some extent by floor sweepings, but the sand from which the oil-sand cores were made would in the first place have been found to give the properties desired of the moulding sand, whilst the floor sweepings would also be found to be of suitable grain size.

It was quite true that some sand was carried away on the castings, and in most cases this was not considered worth recovering, so that sufficient sand from outside sources had to be brought in to replace it. With a synthetic sand, this represented the whole of the new addition, but with a natural sand, sufficient new sand to keep up the strength had to be added, and this was usually a much larger quantity. Accordingly a corresponding amount of used sand had to be withdrawn from the system to make way for the new, and all so withdrawn had to be dumped, although it might be quite a good sand except for a slight deficiency in strength.

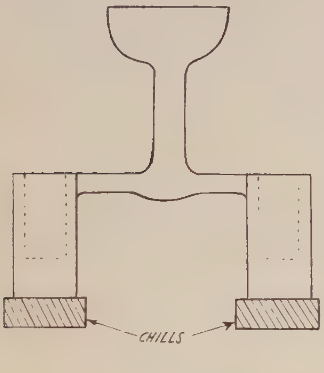
Moulding Steam Valve Lids for Marine Service

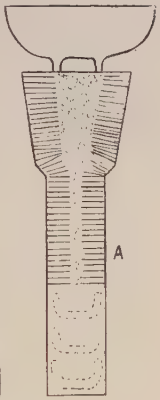
AUTHOR'S ADDENDUM TO PAPER No. 732 AND EAST MIDLANDS BRANCH DISCUSSION

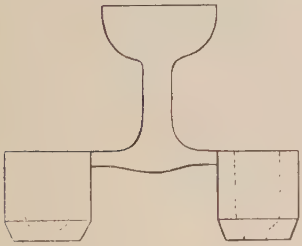
Since Mr. F. Hudson's (Member) Paper was published in "Proceedings," Vol. XXXIV, further experience has been gained in the production of small lids around 1 in. in dia.

The author, therefore, makes the following addendum to his Paper:—

It has been found that manufacturing these from vertically cast bar as shown in Fig. 5 is not too satisfactory, due to the presence of fine porosity at the centre of the closed end, as shown at A in the attached sketch. This porosity is due to shrinkage. Apparently the formation of the primary crystals in small sand-cast bars, or a rapid drop in fluidity due to temperature decrease in the alloys employed, is sufficient to prevent definite solidity being obtained throughout the section. Trouble in this direction has been overcome by production of individual castings, as illustrated herewith. It is important to note, however, that these modified methods only apply to very small castings, and are not successful with diameters over $1\frac{1}{2}$ in. when the methods previously described should be employed. If sound sand-cast bars are desired it appears preferable to make them in a manner similar to test bars, as shown at C and E in Fig. 9. Alternatively one could, of course, use wrought bars, but care will have to be taken in the selection of the material employed, as many of the cast alloys used for steam valve lids are not workable. It has been found that rolled Monel or "K" Monel bars provide a satisfactory substitute in the majority of cases for the production of small lids working in contact with stainless steel seats.







The discussion following the presentation of the Paper before the East Midlands Branch (see below) drew attention to the large weight of metal going into the feeding heads in comparison to that in the castings, particularly if the runner bush was also allowed to retain metal. Whilst little can be done to reduce the size of feeding heads, care should be taken to see that pouring is stopped in time for the runner bush to empty itself in order to get the highest possible yield of castings to metal melted. There is, however, no positive method of seeing when the mould is full, and the best way of conserving metal during pouring is to fit a large runner bush which will hold just slightly more metal than required for the casting excluding head. It is then a relatively simple matter to commence pouring by filling the runner basin rapidly, and to interrupt pouring for a moment so that the runner bush can empty itself and then add further metal to bring the head up to the bottom of the jet runners.

EAST MIDLANDS BRANCH DISCUSSION

MR. H. J. BECK asked for the ratio of feeder head to castings, and suggested that Mr. Hudson went further into the proposed method of feeding and altered the shape of the feeder head from a straight taper to a parallel cylinder with a spherical base, $\frac{3}{4}$ in. larger in diameter than the boss on the castings with a feeder saddle on the pattern equal in size to the pattern boss, standing $\frac{3}{16}$ in. high and slightly tapered towards the feeder head to define the cutting off line. This type of feeder head would ensure that the metal was kept liquid longer than the tapered type, and therefore the feeder head could be appreciably reduced in height.

MR. HUDSON said that the weight of feeder heads in the majority of cases was fully equal to the weight of the castings. Foundrymen producing these castings might be able to decrease the size of heads, but personally he was not prepared to say that these should be reduced as a general principle. He agreed with Mr. Beck's remarks in connection with the modified form of feeding head and considered there was a great deal to be said for a sudden thickening of the head as it left the casting, as illustrated in Fig. 4 of the Paper, in comparison with the straight taper type shown in Figs. 1 to 3. He did not altogether agree, however, that a parallel cylindrical feeder was an advantage even if this was of a much greater diameter than the casting section. There was much to be said for tapering the riser above the shouldered portion to assist progressive solidification.

Progressive Solidification

MR. A. E. PEACE thought that it must be due to wartime censorship that Mr. Hudson had been unable to give the composition of the alloys that he was dealing with, but it was clear that these were high-nickel alloys, and he felt that many people who were not experienced in non-ferrous work would have been astonished at the extent to which the elimination of cores and the adding of metal to effect a progressive solidification had been taken, but it should be borne in mind that these metals were expensive, and the ratio of the metal cost to the productive labour cost was entirely different from that of cast iron, and the machining to remove the added metal was simple and consisted largely of drilling.

Another aspect was the matter of high temperature casting. He felt that in speaking of the shrinkage of metals it was necessary to understand the metal under consideration, and as he was not familiar with these alloys, he wondered if Mr. Hudson could briefly and in a simple way enlarge upon the consideration of these metals from the phase aspect because all these were of course of paramount importance in the shrinkage of the metal. There were two aspects of this temperature of importance, one was that casting hot involved a greater amount of liquid shrinkage, and the other that when such hot metal was provided the feeders were more effective. The correct way of feeding seemed to be not just a case of knowing where to put a feeder but also where to run the metal, and he thought that perhaps Mr. Hudson could enlarge upon that. There obviously was a need for some simple method of determining how a casting cools and solidifies.

MR. HUDSON said that in general the alloys used for lids of the type shown were nickel-copper alloys hardened with small additions of tin, silicon, manganese or iron. They had a relatively short freezing range in comparison with gunmetal and bronze and a high linear shrinkage, and must be cast on similar lines to steel, *i.e.*, relying upon temperature to provide an adequate measure of fluidity for feeding purposes. It was difficult to enlarge upon methods of moulding as suggested by Mr. Peace, as most of the types of lids in service had been covered. If any member, however, had a particular design of casting in mind which might be moulded by the methods described he would be pleased to comply with Mr. Peace's suggestion.

Cast-on Test-Bars

MR. F. DUNLEAVY said that several years ago he presented to the Branch the results of a few simple experiments with four phosphor bronze gear blanks. These castings were poured through a strainer core into a 1-in. down runner, then into a heavy well approximately 3½ in. dia. by 4 in. deep. The majority of the members considered this method had distinct possibilities, but unfortunately he had been unable to pursue the matter any further. Mr. Hudson had proved this theory in practice, a problem which a large number of people have been trying to solve for years. Controlled feeding under the conditions illustrated had certainly proved their value, and the most important feature seemed to be that the riser contained the hottest metal adjacent to the place where it was required. The riser metal was totally enclosed, and therefore free from contamination by the atmosphere. The methods suggested in the Paper ought to bear fruitful results in the future in the production of high nickel materials. He asked Mr. Hudson if it was the usual practice to ask for cast-on test-bars in Monel metal, and in particular for Monel metal impellers. Personally he did not think that it was advisable to attempt this. He believed that complete control of the metal composition was essential when making castings in Monel, as without the control results were variable.

MR. HUDSON replied that he was very pleased to have Mr. Dunleavy's confirmation of the moulding methods suggested. Regarding the question of test-bars in connection with Monel impellers, he thought it would be most unwise to attempt to produce "cast-on" bars.

Manganese Bronze Castings

MR. S. H. RUSSELL said he had been very interested in Mr. Hudson's Paper, because many works were producing quantities of manganese bronze castings which present many parallel problems. With this alloy, turbulence during pouring frequently had serious effects, and he was afraid that they could not adopt Mr. Hudson's method of top running in many cases. Referring to the illustration of the test-piece cast at the bottom of a large feeder, did Mr. Hudson think that a chill placed on the bottom of this test-piece would give an improved result? Mr. Russell endorsed the lecturer's remarks regarding the necessity of allowing sufficient taper on deep sections to permit progressive solidification and satisfactory feeding, and illustrated an example produced recently in the foundry using this method. He also expressed considerable interest in the plumbago wash used on the dry sand moulds, and was of opinion that the details given by Mr. Hudson were very helpful in producing a wash which would withstand the high temperatures of certain alloy castings.

MR. HUDSON agreed that the application of top running methods to high tensile brass might prove a practical proposition, particularly with those alloys containing a low aluminium content. A Paper by Higgins in the "Iron Age" (May 8, 1941) outlined the successful production of high-tensile brass castings by such methods, and it was particularly mentioned that no trouble had arisen through the presence of turbulence nor the formation of dross. Trouble might arise with those brasses containing appreciable aluminium contents, but top running methods would have to be tried out in order to confirm the matter. It would be extremely useful if some practical experiments on these lines could be undertaken by some of the members. Regarding the application of chills to test-bars, this was not usually necessary. If chills were used extensively on the casting they might be applied to the test-bars. Care should, however, be taken to prevent excessive chilling of test-bars made from alloys containing tin, as brittleness or low ductility might result.

Heavy Machining Allowances

MR. R. H. BUCKLAND suggested that it was rather amazing that it had been possible to allow ½ in. or more machining allowance on a number of machined surfaces. He was sure that some members would be pleased if similar tolerances could be accorded with cast and malleable iron. Monel metal was very expensive, and arising out of Mr. Dunleavy's remarks, apparently little or no attention was given to reducing feeder heads wherever possible. Surely the introduction of chills in the bottom of the mould, with the resultant increase in rate of solidification, would enable one to reduce the necessary size of feeder head. Mr. Hudson had referred to the objection of the engineers to the practice of casting in a pintle. Was the objection due to the fact that there was a possibility of the pintle working loose in service? If this were the trouble, it might be overcome by altering the method of running the casting, by introducing some hot metal into the bottom of the mould adjacent to the pintle. Perhaps Mr. Hudson would give his views on this point.

MR. HUDSON said the alloys used for steam valve lids were, as Mr. Peace pointed out, expensive to produce in the foundry and in the machine shop and accordingly every precaution taken to ensure good castings is in the long run likely to promote economic working. Short cuts to solidity by the use of chills were to be deprecated unless these were designed to assist progressive solidification. Furthermore, it should be understood that the technique of chilling as applied to cast iron did not work out in the same direction for non-ferrous alloys. In regard to pintles on valve lids engineers had, in the past, been afraid that these may come detached in service when joined by mechanical means. This objection was of course eliminated by "casting-in."

Cast-in Pintles and Gas Evolution

MR. E. HOLLAND wrote that he was particularly interested in the portion of the Paper dealing with test-bars and cast-in pintles. Regarding the former, the slides showing test-bars machined almost out of solid, seemed to indicate a very expensive method. Providing these were not more than 7 in. long, could not the recess be filled up, tapering from top to bottom and casting on end, thus ensuring a more evenly progressive shrinkage and a more regular shape for the initial machining? The clover-leaf pattern approached very closely to this, but was there not a possibility of uneven solidification between the outside of the leaves and the centre, as well as the waste of fuel in melting extra metal for the centre portion and extra metal in feeder head to feed this? It would be noted that the word uneven was used as against progressive, as where the cooling range was quickest there would be a denser structure than where this was delayed in spite of progressive solidification.

With regard to the inserted pintle, he would be interested to learn whether there was not a danger of gases being generated from this steel insert at the high pouring temperature of the metal. Mr. B. Hird in a Paper entitled "Grey Iron Problems," given before the Branch and printed in "The Foundry Trade Journal" of November 28, 1940, dealt with this problem with reference to steel inserts in cast iron. If Mr. Hird's theory was correct, then it must occur in any metal at a sufficiently elevated temperature.

MR. HUDSON, referring to test-bars, said it was doubtful as to whether any advantage would be gained by vertically casting even if the bars were well tapered unless large diameters were employed and the machining of these down to size would be just as expensive as those shown in the Paper. In small diameter vertically-cast bars the primary crystals formed tended to obstruct feeding action and difficulty was likely to be experienced in getting the centre sections sound. Accordingly the bar would have to be made, having a diameter large enough to ensure that the growth of the primary crystals did not interfere with feeding. Furthermore, the variation in section of a vertically-cast taper bar would probably give rise to a variation in structure along its length with consequent erratic results on test. Reference might well be made to Kain and Dowson's Paper, Proc. I.B.F., 1939-40, page 61, mentioned in connection with the development of the clover-leaf pattern. In regard to the "cast-in" pintle, there would be little danger of gases being generated when using a Monel or stainless steel (18/8) pintle. If, a steel containing appreciable carbon content was employed, trouble might be experienced due to gas.

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